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OFFICE OF MANNED SPACE FLIGHT

APOLLO PROGRAM

APOLLO RELIABILITY AND QUALITY ASSURANCE PROGRAM QUARTERLY STATUS REPORT (U)

FOURTH QUARTER 1965

7 JANUARY 1966

PREPARED BY

APOLLO RELIABILITY & QUALITY ASSURANCE OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

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APOLLO RELIABILITY
AND
QUALITY ASSURANCE PROGRAM
QUARTERLY STATUS REPORT (U)

FOURTH QUARTER 1965

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~~Group 4~~
~~Downgraded At 3-Year Intervals;~~
~~Declassified After 12 Years,~~
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Prepared by

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Washington, D.C. 20546

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The following parts of this document are CONFIDENTIAL:

Summary - pages xv through xxiv

Section 1 - pages 1-1 through 1-64

Section 2 - pages 2-1 through 2-60

FOREWORD

Apollo Program Reliability and Quality Assurance Status Reports are prepared quarterly by the Reliability and Quality Assurance Program Office for the Apollo Program Director based upon an analysis of information supplied by Reliability and Quality Assurance groups at the Manned Space Flight Centers in Houston, Huntsville, and Cape Kennedy. These reports document accomplishments during the period, current status of the Reliability and Quality Assurance Program, and action planned for continuing reliability improvement in the management and hardware areas of the Apollo Program.

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SUMMARY

GENERAL

This status report documents the progress of the Apollo Reliability and Quality Assurance Program during the fourth quarter of 1965 in the three major areas of Apollo-Saturn IB flight missions, Apollo-Saturn V flight missions, and Reliability and Quality Assurance Program Management.

Sections 1 and 2 contain current reliability and quality assurance status of the launch vehicles, spacecraft, and ground support systems associated with the Apollo-Saturn IB and Apollo-Saturn V missions. Reliability analyses of the Apollo-Saturn 202 and 504 missions are included. Section 1 also contains latest status relating to preparation of the Flight Readiness Review - Part 1 for the Apollo-Saturn 201 mission. Reliability analysis summary of this mission was presented in the Third Quarter Status Report and is not repeated herein. Status of the R&QA Program Management activities during the report period are presented in Section 3.

APOLLO-SATURN IB FLIGHT MISSIONS

SIGNIFICANT ACCOMPLISHMENTS

The following accomplishments highlight the Reliability and Quality program progress of the early Apollo-Saturn IB flight missions during the reporting period:

a. All contractors for launch vehicle stages, spacecraft, and supporting GSE completed a reliability assessment of the Apollo-Saturn 201 flight mission equipment.

b. Requirements of NPC 250-1 contractually required of the Saturn IB launch vehicle contractors were increased from 90 to 94 percent. Of this 94 percent, approximately 78 percent compliance was evidenced during the reporting period.

c. The first analysis of the launch vehicle contractors quality programs was conducted by Marshall Space Flight Center. Both of the stages reviewed (IU and S-IVB) were considered in excellent condition.

d. All mandatory ground and qualification testing in support of the Apollo-Saturn 201 flight was completed or waivers were granted by the responsible Centers.

SUCCESS PREDICTION

For the second launch (202) in the Apollo-Saturn IB series, the major elements of risk are evenly divided between the S-IB stage, the S-IVB stage, and the spacecraft. The relative contributions to unreliability based on predicted values are depicted in Figure A.

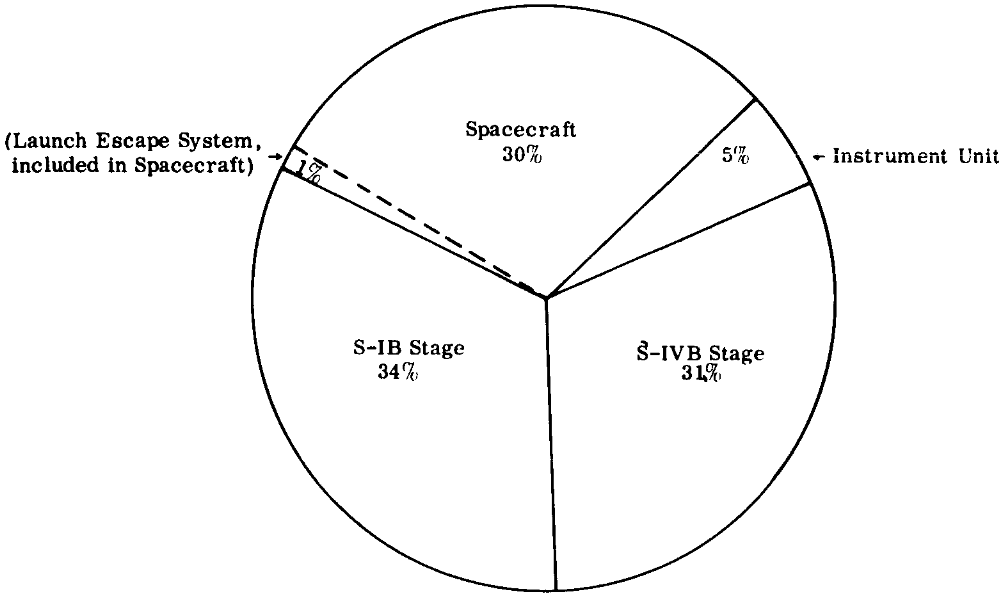

Figure A. AS-202 Stage Percentage Contribution To Unreliability

Prediction values indicate a mission success probability of 0.90 which exceeds the allocated goal of 0.85. Figure B shows both the conditional and over-all predicted probabilities as a function of mission phase. A stage-by-stage comparison of probable reliability and allocated goals based on prediction values is shown in Figure C.

In the event of a major malfunction in the 202 mission launch vehicle, action is initiated either automatically by the emergency detection system or by back-up command from the ground to permit recovery of the Command Module. The probability of contingency (abort) success, given that an abort is required, was computed as 0.993 using the Launch Escape Subsystem and 0.983 using the Service Propulsion Subsystem for separation power.

IMPROVEMENT ACTION

Action for reliability program improvement in the next reporting period will be concentrated as indicated in the following paragraphs.

Flight Readiness Review

Based upon the flight readiness review on the Apollo-Saturn 201 mission scheduled one week prior to launch, Center procedures and OMSF requirements will be reviewed to upgrade the quality of flight readiness reviews for subsequent missions.

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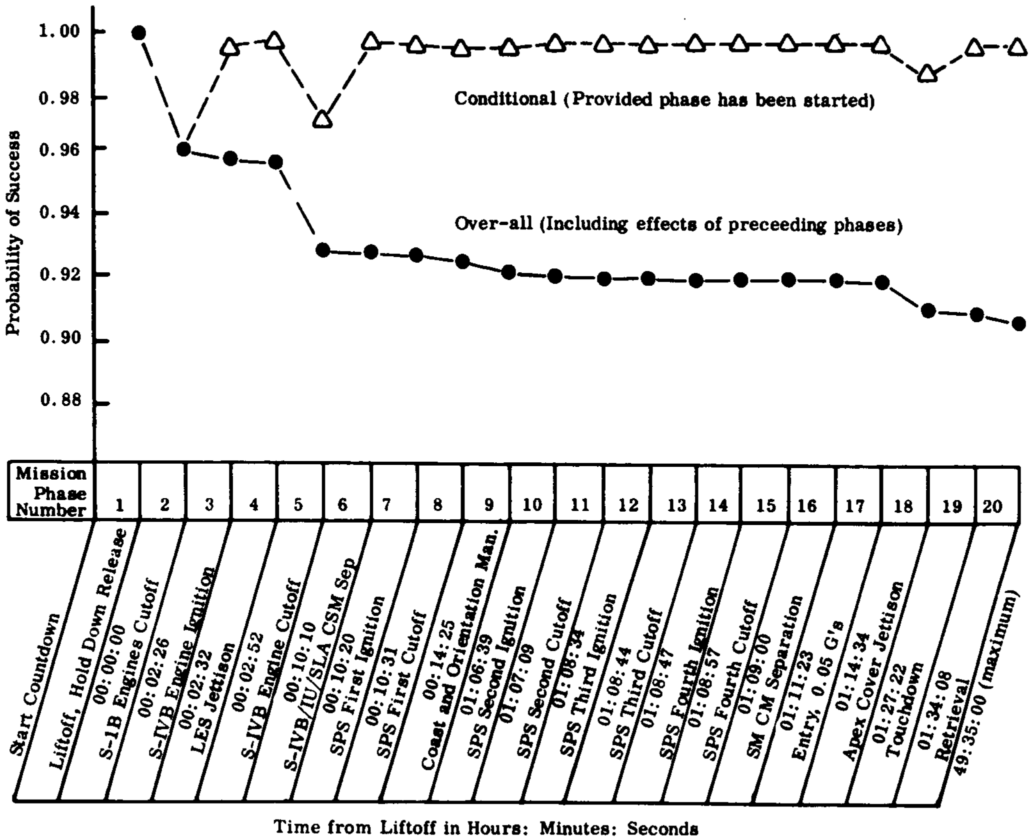


Figure B. Apollo-Saturn 202 Mission Success Predictions

Apollo Program Specification (Reference)			Mission Success			
			AS-201		AS-202	
Phase	Equipment	Success Probability	Prediction	Assessment (Preliminary)	Prediction	Assessment (Preliminary)
Flight*	S-IB	0.95	0.95	0.96	0.97	
	S-IVB	0.95	0.97	0.96	0.97	
	IU	0.99	0.99	0.99	0.99	
	CSM/LES	0.96	0.98		0.97	
	LEM/Adapter	0.98	1.0**		1.0**	
	Over-all (computed from stage numbers above)	0.85	0.90	0.90	0.90	

* The flight phase begins with space vehicle liftoff from the launch pad and terminates with recovery of the CM.
**Adapter structure only. There is no LEM in AS-201 or AS-202 (adapter separation is included in CSM/LES number).

Figure C. Comparison of Goals with Prediction/Assessments

[redacted]

Flight Reliability Evaluation

A review of the flight results of the Apollo-Saturn 201 mission will be conducted and specific recommendations for reliability improvement on subsequent flight hardware will be coordinated with the MSF Centers.

Qualification Test Ground Rules

A review of the qualification test ground rules for the launch vehicle stages will be conducted with MSFC with the intent of finalizing a common base from which schedule completions versus plan can be evaluated against the effect on reliability for specific launch vehicles.

Quality Program Evaluation

An evaluation of the S-IB and Electrical Support Equipment (ESE) contractors contractual requirements invoking NPC 200-2 and the degree of compliance with which the contractors are implementing these requirements will be conducted during the next reporting period.

Spacecraft 012 Structural Integrity

The structural integrity of Spacecraft 012 is in question due to the large number of reported structural nonconformances. Further investigation is planned in order to make appropriate recommendations.

APOLLO-SATURN V FLIGHT MISSIONS

SIGNIFICANT ACCOMPLISHMENTS

During the reporting period, the following significant accomplishments were made:

a. The Apollo R&QA Program Office has discussed the criticality of the S-IVB jettison to lunar orbit insertion phase with cognizant personnel at the Manned Spacecraft Center (MSC). Initial approaches involving operational ground rule changes to reduce the criticality of this phase have been documented in the previous quarterly report. A study of the effect of ground rule changes on the probability of mission success has been completed.

b. During this quarter, a data search was conducted to determine the availability of "time-to-failure" and "time-to-restore" data for Apollo mission-essential equipment during the prelaunch phase of mission. Because this data was not available, previous countdowns were analyzed for application to the Apollo Program.

   Using a high-level analytical simulation model, a parametric analysis of the prelaunch phase was initiated to determine the probabilities of launch based on best, nominal, and worst-case failure rates and on time-to-repair data. However, the results of the parametric analysis will be available during the first quarter of 1966. The results will be published in a technical report to be issued in the near future.

c. Reliability analysis of the Ground Operational Support System (GOSS) was continued using currently available and applicable program documentation.

The GOSS - space vehicle functional interrelationships have been defined in terms of mission-essential functions supported by GOSS. GOSS station coverage and space vehicle system requirements on the Manned Space Flight Network as described in current Apollo Program documents have been correlated with the nominal mission time line of the Design Reference Mission Reliability Profile. This information has been summarized and is available in chart form for each stage/module of the space vehicle. Requirements on GOSS by the Spacecraft Guidance and Navigation (G&N) system during the more hazardous phases of the mission have been analyzed to determine the need of immediate Manned Space Flight Network availability for abort initiation. A GOSS station and equipment indenture listing and corresponding logic diagram construction have been initiated.

d. Eighty-eight percent of the requirements of NPC 250-1 are contractually required of the Saturn V launch vehicle contractors. Of this 88 percent requirement, 76 percent are being implemented.
e. Quality program charts indicating evaluation of NPC 200-2 implementation on Saturn V launch vehicle stages and (GSE) are included for the first time. Over-all implementation is considered excellent.

SUCCESS PREDICTION

Updated estimates of crew safety and mission success probabilities for the Apollo-Saturn 504 Manned Lunar Landing Mission were prepared from reliability analysis conducted for the R&QA Program Office. Center/contractor reliability data on the subsystem and equipment level are used as part of the input data to the Apollo-Saturn 504 mission simulation model; the resulting quantitative reliability estimates are referred to in this report as the Apollo Program Office reliability estimates. Figure D shows the percentage contribution to present predicted total mission unreliability by stages and modules.

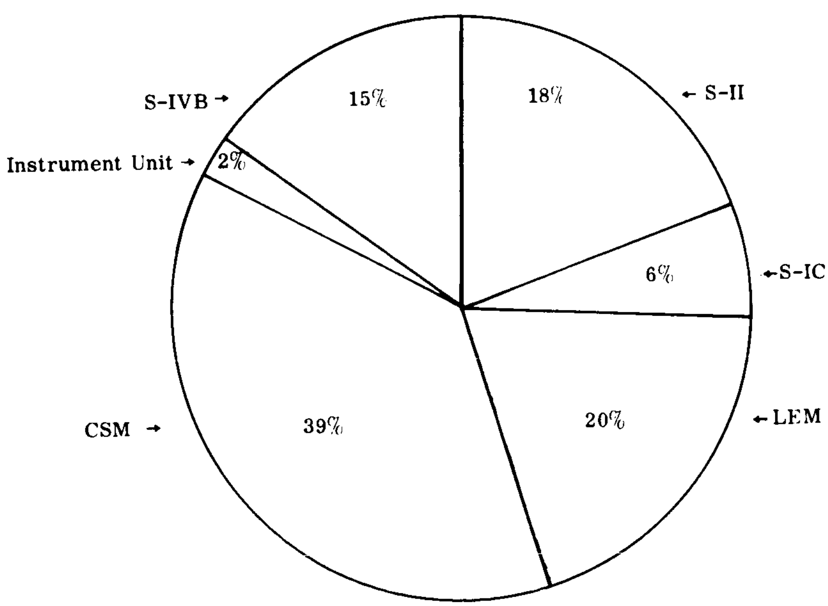


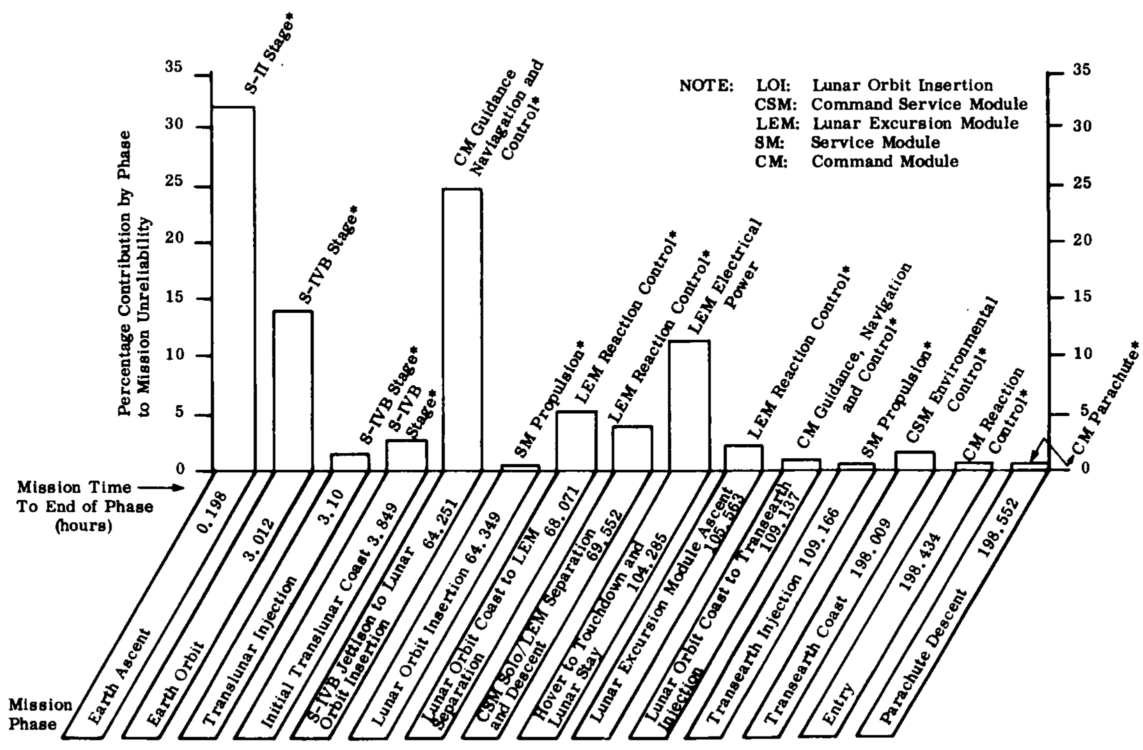
Figure D. AS-504 Stage Percentage Contribution to Unreliability

The logic of the mission simulation was updated to take advantage of equipment redundancy in the Command/Service Module Environmental Control system. This reduced the criticality of the Transearth-Coast phase, with respect to the probability of crew loss, from first to third rank. The two most hazardous mission phases are the Hover to Touchdown and Lunar Stay phase, and the S-IVB Jettison to Lunar Orbit Insertion phase.

A decrease in S-IC stage success probability, based on updated Center/contractor reliability prediction data, causes the Earth Ascent phase to rank first and the S-IVB Jettison to Lunar Orbit Insertion phase to rank second with respect to the probability of mission loss. However, the probability of crew loss in the Earth Ascent phase is considerably less than in the S-IVB Jettison to Lunar Orbit insertion phase.

The percentage contribution to mission unreliability by the fifteen mission phases and the major system contributor to mission unreliability in a given phase are shown in Figure E.

Based upon updated Center/contractor reliability apportionment data, the values of crew safety and mission success probability for the Apollo Saturn 504 mission are 0.99 and 0.81, respectively.



*Most unreliable system within mission phase

Figure E. Percentage Contribution by Phase to Mission Unreliability versus Mission Phase (AS-504 Mission)

Based upon available updated Center/contractor reliability prediction data, the estimates of crew safety and mission success probabilities are 0.98 and 0.54, respectively. Figure F shows both predicted probabilities as a function of mission phase.

IMPROVEMENT ACTION

The R&QA Program Office activity during the next quarter will be directed toward reliability improvements as indicated in the following paragraphs.

S-IVB Jettison to Lunar Orbit Insertion Phase

The findings of completed analysis of the effect of ground rule changes on the probability of mission success will be included in a technical report to be issued by the Apollo R&QA Office in the next quarter.

Launch Availability Analysis

The R&QA Program Office will continue analysis and publish preliminary results in a technical report. The report will be issued during January 1966.

GOSS Reliability

The R&QA Program Office will continue analysis of the GOSS/space vehicle functional interrelationships and report on progress during the next quarter.

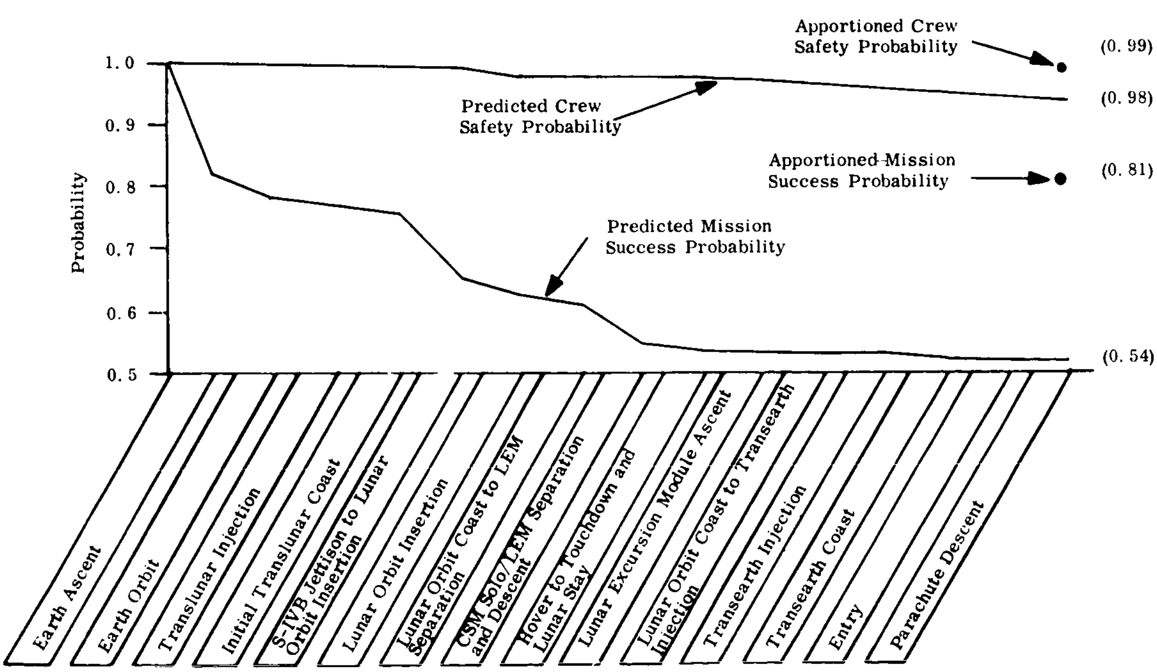


Figure F. Mission Success and Crew Safety Probabilities versus Mission Phase (AS-504 Mission)

RELIABILITY AND QUALITY ASSURANCE PROGRAM MANAGEMENT

SIGNIFICANT ACCOMPLISHMENTS

During the reporting period, Apollo Reliability and Quality Assurance Offices initiated or implemented additional plans for the continuing improvement of program reliability through the coordinated use of more effective reporting, measurement, and control techniques. Included were the following:

a. The Saturn V Program Office is presently engaged in developing the initial Saturn V Reliability Quarterly Status Report for issuance on March 15, 1966. A monthly Quality Status Report will also be issued beginning in January 1966.

b. The KSC Apollo R&QA Program Office issued the initial R&QA status report in November 1965. Subsequent reports will be issued quarterly beginning in January 1966.

c. As a result of bimonthly Program reviews, MSF Centers have recognized the need for timely and accurate failure information and are taking the steps necessary for improvement.

d. Under the direction of the Apollo R&QA Offices, two new reliability training courses have been implemented. These are the "Reliability Engineering Seminar" and the "Electromagnetic Compatibility Awareness Seminar".

e. The Apollo Metrology Handbook is scheduled for publication in December 1965 as NHB 5300.2.

f. A review of acceptance and buy-off procedures for Launch Complex 37B and GSE at KSC has been initiated. As the initial example, the review has encompassed the S-IVB Auxiliary Propulsion system. The review indicates written procedures have been prepared for the installation of this system and were patterned after the LC-34 installation, but no documentation has been located that defines the total APS system.

g. A presentation of the Reliability Mission profile based on the Design Reference mission was given to MSFC by the Apollo R&QA Office on 15 November 1965.

h. The Apollo R&QA Office conducted a review of the spacecraft model at MSC on 30 November through 2 December.

IMPROVEMENT ACTION

During the next reporting period, action will be taken for program improvement as indicated in the following paragraphs.

Program Audits

There has been an improvement in the timeliness of corrective action by MSC contractors relative to problems uncovered by Quality System audits. However, it continues to be a major problem and the Apollo R&QA Office will continue to review MSC improvement activities.

System Nonperformance Analysis

An Apollo Program Directive for Failure Reporting will be issued to formalize requirements for preparation of failure data. Upon issuance, the Apollo R&QA

Office will assist MSF Center personnel to implement the requirements of the directive.

Single Point Failure Analysis

An Apollo Program Directive which formalizes previous instructions and establishes coordinated operating procedures for reporting and controlling potential single-point failures will be issued. Apollo R&QA Office personnel will coordinate the implementation of this directive with MSF Center personnel.

KSC Acceptance and Buy-off Procedures

A review of KSC procedures initiated during this period will continue to determine whether important details that are not specifically a part of any one of the S-IVB Auxiliary Propulsion system components have been overlooked due to the lack of a total system description. The review will further assess procedures and actions associated with acceptance of LC-37B and other GSE at KSC.

Implementation of R&QA Requirements

Motorola, manufacturer of the Unified "S" Band Transponder, has received R&QA requirements that vary in some areas from Apollo contractors and MSF Centers. Representatives from Apollo contractors, MSF Centers and APO met with those from Motorola in September to discuss the problems. A detailed program was planned, and schedules were established to resolve the differences. As a result of this meeting, the participating Apollo contractors are now coordinating proposed amendments to the NASA soldering specification, NPC 200-4. The Apollo R&QA Office will maintain surveillance to assure final resolution of the specification problem.

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SECTION 1: APOLLO-SATURN IB MISSIONS

1.1 GENERAL

1.1.1 INTRODUCTION

This section contains a discussion of the reliability program status for the Apollo-Saturn IB missions obtained by analysis of NASA/OMSF, NASA Center, and contractor documentation. Specific emphasis has been placed on the imminent launch of Apollo-Saturn 201 and on an analysis of the Apollo-Saturn 202 mission.

Major accomplishments during the reporting period include the following:

a. Completion of all mandatory ground and qualification testing in support of the Apollo-Saturn 201 mission.
b. Performance of quality assurance evaluations on three of the Saturn IB launch vehicle contractors by the MSFC Reliability and Quality Assurance Office.
c. The first reliability assessment by the launch vehicle stage contractors on their respective stages for the Apollo-Saturn 201 mission.
d. Completion of the functional reliability elements for use in the S-IB-4 reliability model.

Significant problems that could degrade the reliability of early 200-series flights were noted as a result of the Apollo-Saturn 201 launch vehicle reliability assessment. They are:

a. The recognized possibility of a long duration open circuit in the potentiometer used in the flight control actuator assembly of the S-IB stage can cause an oscillation at a control frequency of 0.25 cps with an amplitude of ±3 degrees. A control study conducted by Chrysler Corporation Space Division (CCSD) on Saturn I vehicles concluded that the flight control system would still maintain control under this condition; however, problems could be encountered in achieving proper orbit attitude.
b. The anticipated flight vibration levels for the instrument unit significantly exceed known ST-214-M platform tolerance levels.
c. The calculated worst-case dynamic loads for the instrument unit structures are sufficient to fracture the rivets holding the cable tray to the brackets. Failures have occurred during vibration testing of the 200 V vehicle and on other vibration tests at IBM.

Implementation of the contractual requirements of NPC 250-1 by the Saturn IB launch vehicle contractors is shown on Figure 1-1. During the reporting period, the contractual requirements were increased from 90 to 94 percent with approximately 78 percent of the 94 percent being implemented.

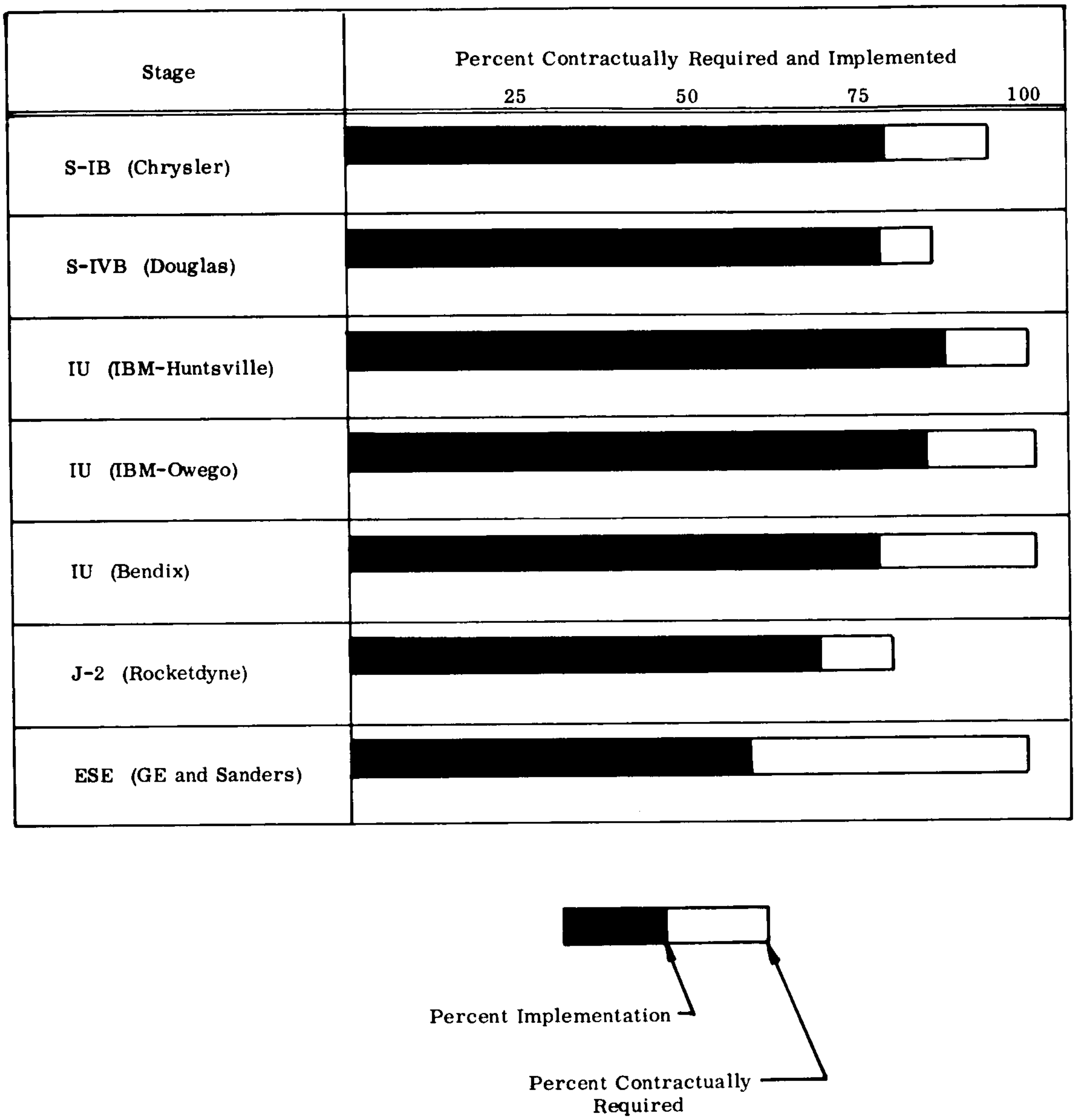

Figure 1-1. Saturn IB Program Summary Reliability Assurance Evaluation Based on NPC 250-1

1.1.2 APOLLO-SATURN 201 MISSION

1.1.2.1 Flight Readiness Review

In preparation for the Program Director's Flight Readiness Review (FRR), for the Apollo-Saturn 201 mission, MSFC held a preflight review on 14-15 December 1965 in which the launch vehicle contractors presented their assessment of the mission readiness of the Saturn IB launch vehicle stages. The assessed reliabilities of the 201 launch vehicle stages are:

S-IB-1 Stage	0.96
S-IVB-201 Stage	0.96
S-IU-201 Stage	0.99

1.1.2.2 Qualification Test Summary

The summary of component qualification status for the Apollo-Saturn 201 mission is shown on Figure 1-2. Waivers with completions of only mandatory test environments and anticipated qualification completions have alleviated the possible degradation of the Apollo-Saturn 201 mission reliability.

1.1.2.3 Ground Support Tests

All mandatory ground support testing on the Saturn IB launch vehicle stages in support of the 201 mission has been completed as shown on Figure 1-3.

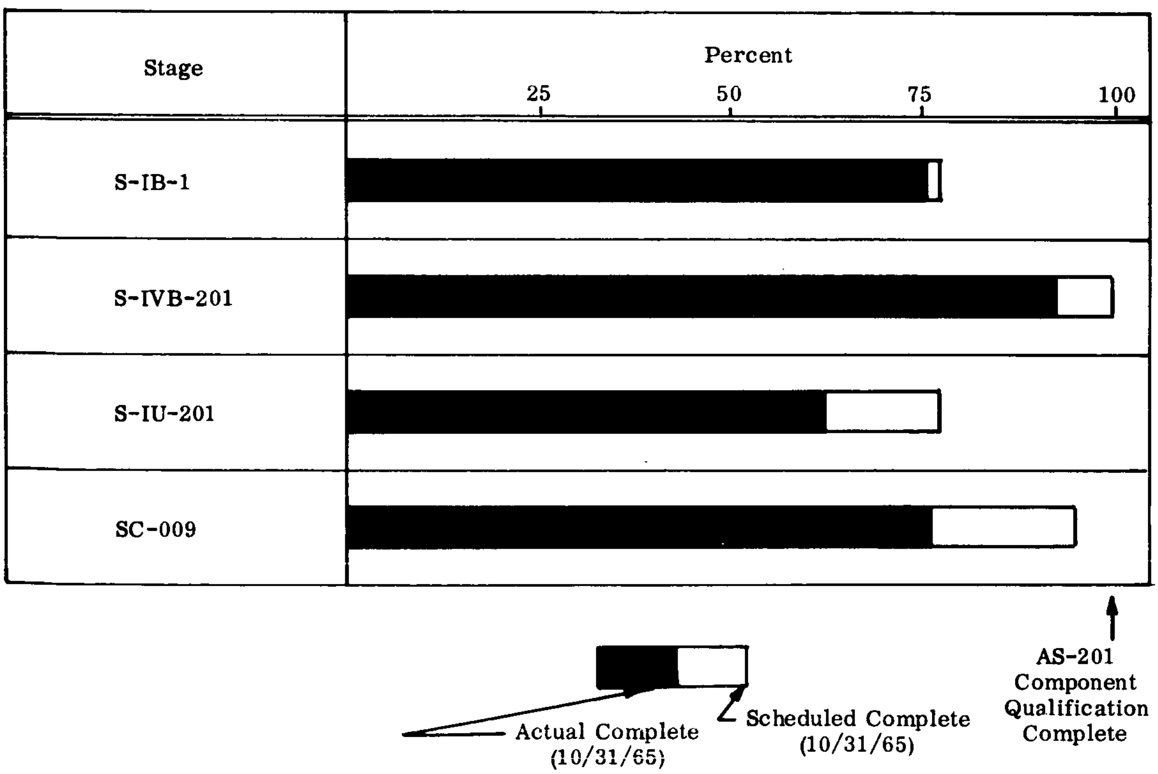

Figure 1-2. Apollo-Saturn 201 Component Qualification Status

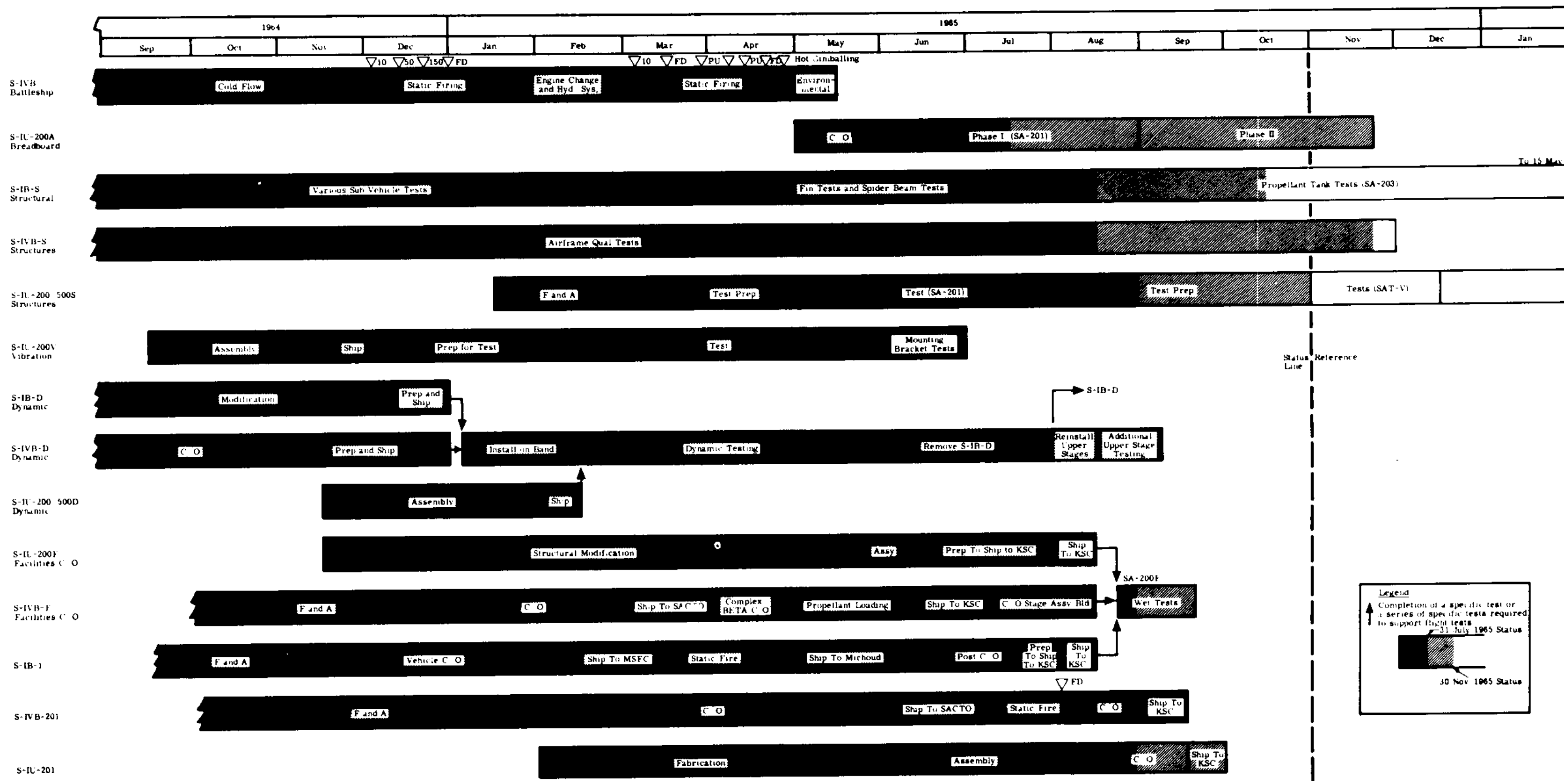

Figure 1-3. Saturn IB Launch Vehicle Ground Supporting Tests

The supporting tests for Spacecraft 009 are complete with the exception of the flight of 002 in mid-December as shown on Figure 1-4. A significant objective of the 002 flight is a demonstration of the structural integrity of the CSM-LES combination.

1.1.3 APOLLO-SATURN 202 MISSION

1.1.3.1 <u>Mission Reliability Analysis</u>

1.1.3.1.1 Summary

A prediction of the probability of the success of the Apollo-Saturn 202 mission has been prepared by the Apollo Program Office (APO) from an analysis of available Center and contractor information. The reliability of the mission and all stages equal or exceed the reliability goals.

The analysis was conducted by means of a reliability model based on the planned mission profile. The mission was divided into phases defined by events which can be monitored during flight. The probability of completing each phase was computed from the models and contractor data. In addition, the probability of successfully accomplishing each mission objective was estimated.

Two types of contingency situations were modeled (see paragraph 1.1.3.1.6), and their probabilities of success were computed using predicted values.

Mission success is defined in the "Apollo Reliability Estimation Guidelines" as "the attainment of all major objectives of the mission as defined in the mission and flight directive...." Data for assessing or predicting the reliability of the Launch Complex and Eastern Test Range (or Ground Operational Support System) were not available; thus, the effects of these systems were omitted from the computations by assuming a value of 1.0 for their reliabilities.

1.1.3.1.2 Mission Profile

No changes were found for the Apollo-Saturn 202 Mission Profile listed in the Quarterly Status Report for the Third Quarter 1965. However, for simplification of computations, several subphases were combined, and all times were rounded to the nearest second. The profile used in the analysis is shown in Figure 1-5.

1.1.3.1.3 Mission Success Goals

No changes have been received in the goals relating to the Apollo-Saturn 202 mission. General S-IB, Instrument Unit, and Block I Spacecraft goals were used as approximations because goals specifically for the Apollo-Saturn 202 mission were not available. The computed probabilities based on goals may be considered pessimistic since the Apollo-Saturn 202 mission involves shorter time periods than does the earth orbital or reference mission (94 minutes compared to over 200 hours).

1.1.3.1.4 Mission Success Predictions

The results of computations for mission success of the Apollo-Saturn 202 mission, using the profile of Figure 1-5, and the system-subsystem predictions listed in

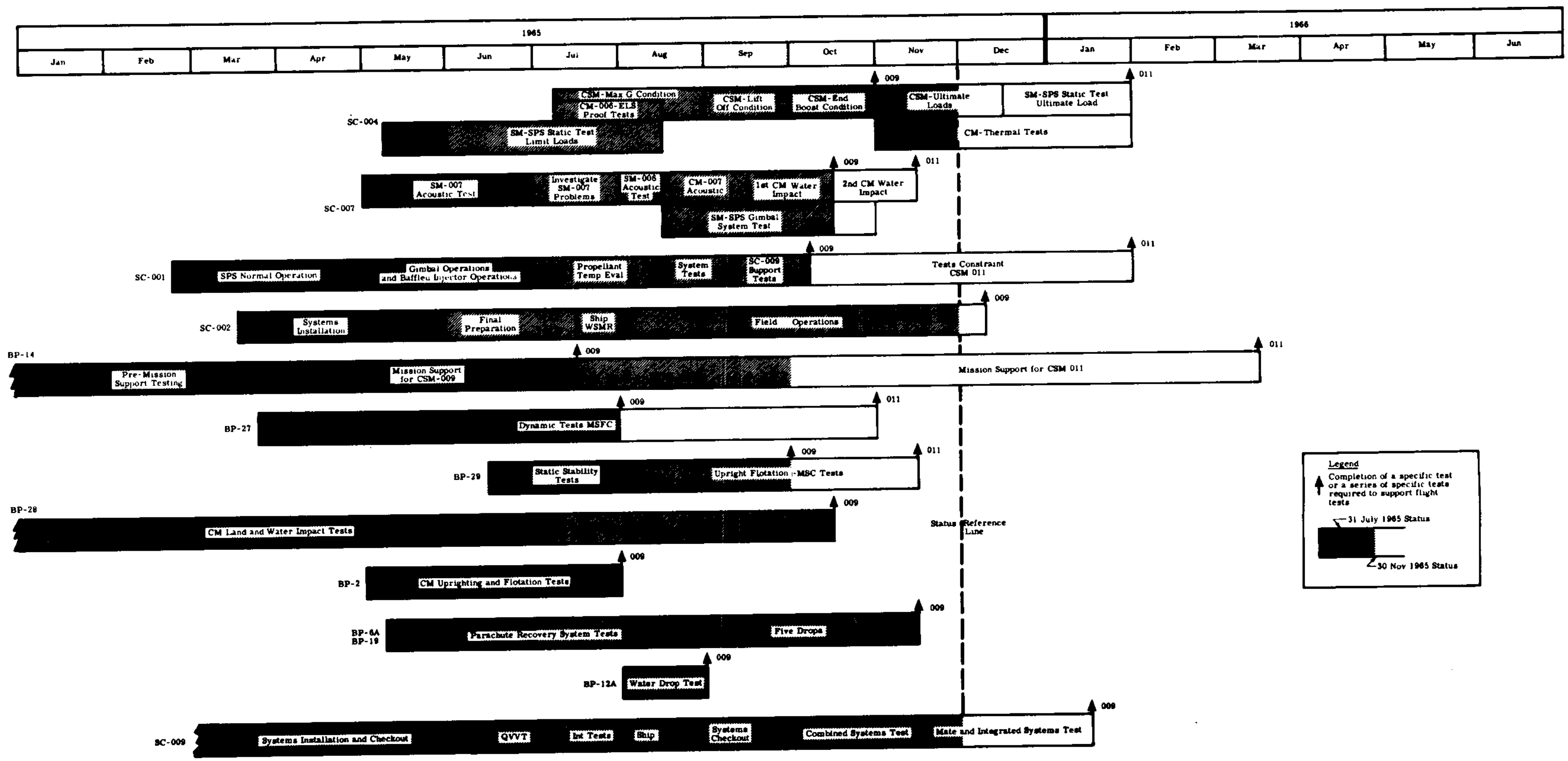

Figure 1-4. SC-009 and SC-011 Apollo-Saturn 201, 202 Missions Supporting Ground Tests

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Events	Elapsed Time (Hours: Minutes: Seconds)	Subphase Number*	Subphase Time in Seconds
Start Countdown			
		1	---
Liftoff, Hold Down Release	00:00:00		
		2	146
S-IB Engines Cutoff	00:02:26		
		3	6
S-IVB Engine Ignition	00:02:32		
		4	20
LES Jettison	00:02:52		
		5	438
S-IVB Engine Cutoff	00:10:10		
		6	10
S-IVB/IU/SLA CSM Separation	00:10:20		
		7	11
SPS First Ignition	00:10:31		
		8	234
SPS First Cutoff	00:14:25		
		9	3134
Coast and Orientation Maneuver	01:06:39		
		10	30
SPS Second Ignition	01:07:09		
		11	85
SPS Second Cutoff	01:08:34		
		12	10
SPS Third Ignition	01:08:44		
		13	3
SPS Third Cutoff	01:08:47		
		14	10
SPS Fourth Ignition	01:08:57		
		15	3
SPS Fourth Cutoff	01:09:00		
		16	143
CM SM Separation	01:11:23		
		17	191
Entry, 0.05g	01:14:34		
		18	768
Apex Cover Jettison	01:27:22		
		19	406
Touchdown	01:34:08		
		20	(48.0 hours maximum)
Retrieval	49:35:00		

*A subphase extends from an event to the next event.

Figure 1-5. Apollo-Saturn 202 Mission Profile

paragraphs 1.2 through 1.5, are shown versus mission time, Figure 1-6, and versus subphase, Figure 1-7. The assumption is made that all flight critical systems are operable (i.e., have a reliability of 1.0) at liftoff.

Since no prediction from the spacecraft contractor was available for the preparation of this report, the Apollo Program Office performed a reliability prediction for the spacecraft. This prediction involved conventional reliability techniques based on available contractor models and reliability data; where contractor information was not available, state-of-the-art failure rates and synthesized logic diagrams were used. Environmental modifying or K-factors were used to account for induced environments occurring during the mission.

In the preparation of the mission computations for this report, reliability predictions data supplied by contractors were used for the launch vehicle.

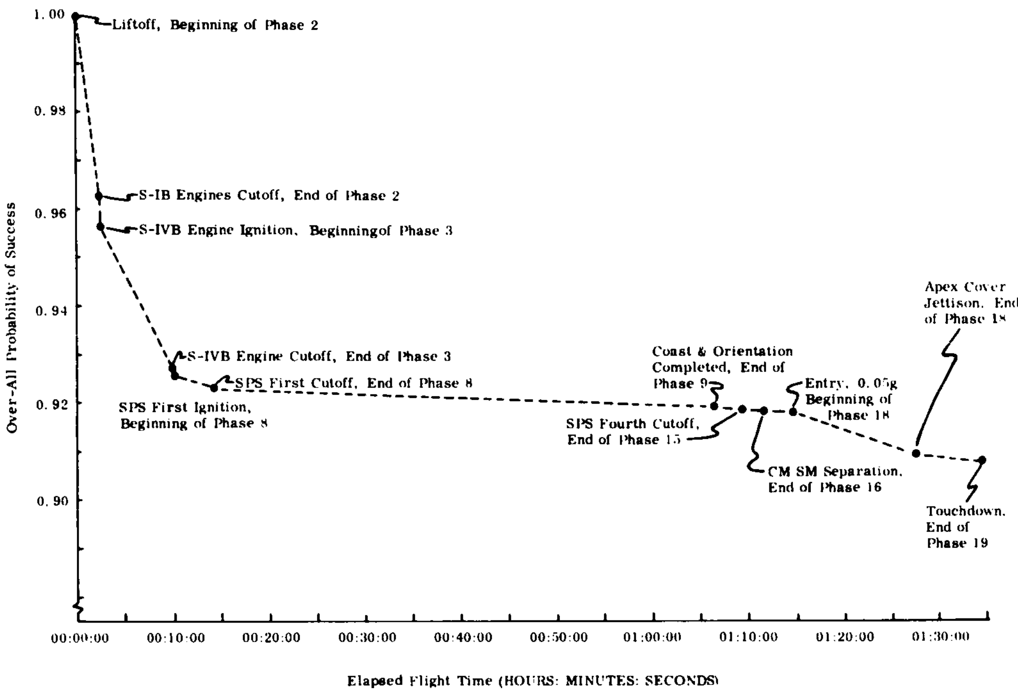


Figure 1-6. Apollo-Saturn 202 Mission Success Predictions

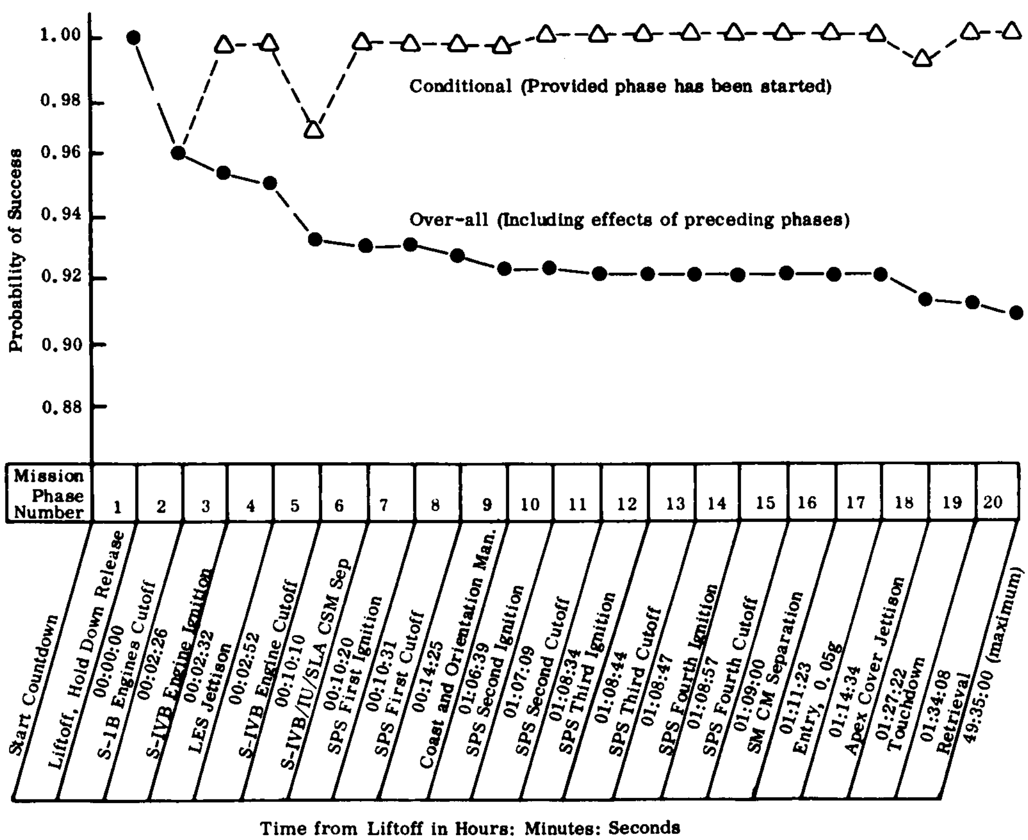


Figure 1-7. Apollo-Saturn 202 Mission Success Predictions

Mission objectives paraphased from the Mission Directive for the Apollo-Saturn 202 mission are listed in Figure 1-8 with the probability for successfully accomplishing each objective indicated. Because the phases used for modeling begin and end with specific events that can be monitored during the flight, the accomplishment of a mission objective may either coincide with the end of a phase or occur during a phase. An accomplished objective may involve the operation of hardware at only one specific time (for example, the separation of the CSM from the S-IVB/IU/SLA), but the start of this event requires the successful completion of all preceding phases. The unconditional or cumulative probability of the mission proceeding to the completion of each objective is listed in Figure 1-8. Conditional probabilities of completion for most objectives (provided the functions involved have been started) are also shown. Conditionals for some objectives could not be calculated because the available system/subsystem breakdown does not permit separation of the systems needed.

1.1.3.1.5 Comparison of Goals and Predictions

For the Apollo-Saturn 202 mission, the reliability predictions for all stages equal or exceed the estimated goals (goals were used for this mission because very few contractual apportionments exist). The over-all probability of mission success as derived from the mission specification and supporting documentation has the goal of 0.85. It is predicted to be 0.90.

1.1.3.1.6 Contingencies

In the event of major malfunction during the interval between ignition of the S-IB engines and separation of the Command and Service Module from the launch vehicle, contingency initiation signal is transmitted either automatically by the emergency detection system or by back-up command from the ground. This action will separate the Command Module from the remainder of the vehicle and allow it to return by means of its Earth Landing System.

Provisions have been made in the Apollo-Saturn 202 mission plans for two types of contingencies (often called "aborts"). Contingency profiles are shown in Figure 1-9. Use of the Launch Escape System (LES) can be initiated at any time from S-IB ignition to the jettisoning of the LES after S-IVB ignition, approximately 170 seconds after liftoff. The Service Propulsion System (SPS) contingency can be used at any time from LES jettisoning to the S-IVB CSM separation, approximately 449 seconds after the LES jettisoning. If either contingency is required, one primary mission objective, "evaluation of the Command Module heat shield at high heat load during entry," cannot be achieved. Other mission objectives which are demonstrated during early phases of the flight may be reached, depending upon the flight time prior to initiation of the contingency. The predicted values of contingency success are computed to be 0.993 for the LES contingency and 0.983 for the SPS contingency.

1.1.3.2 <u>Ground Support Test</u>

The supporting ground tests for the Saturn IB launch vehicles, Figure 1-3 are proceeding according to plan with the exception of the thin-wall propellant tanks for the S-IB stage which are approximately one month behind schedule.

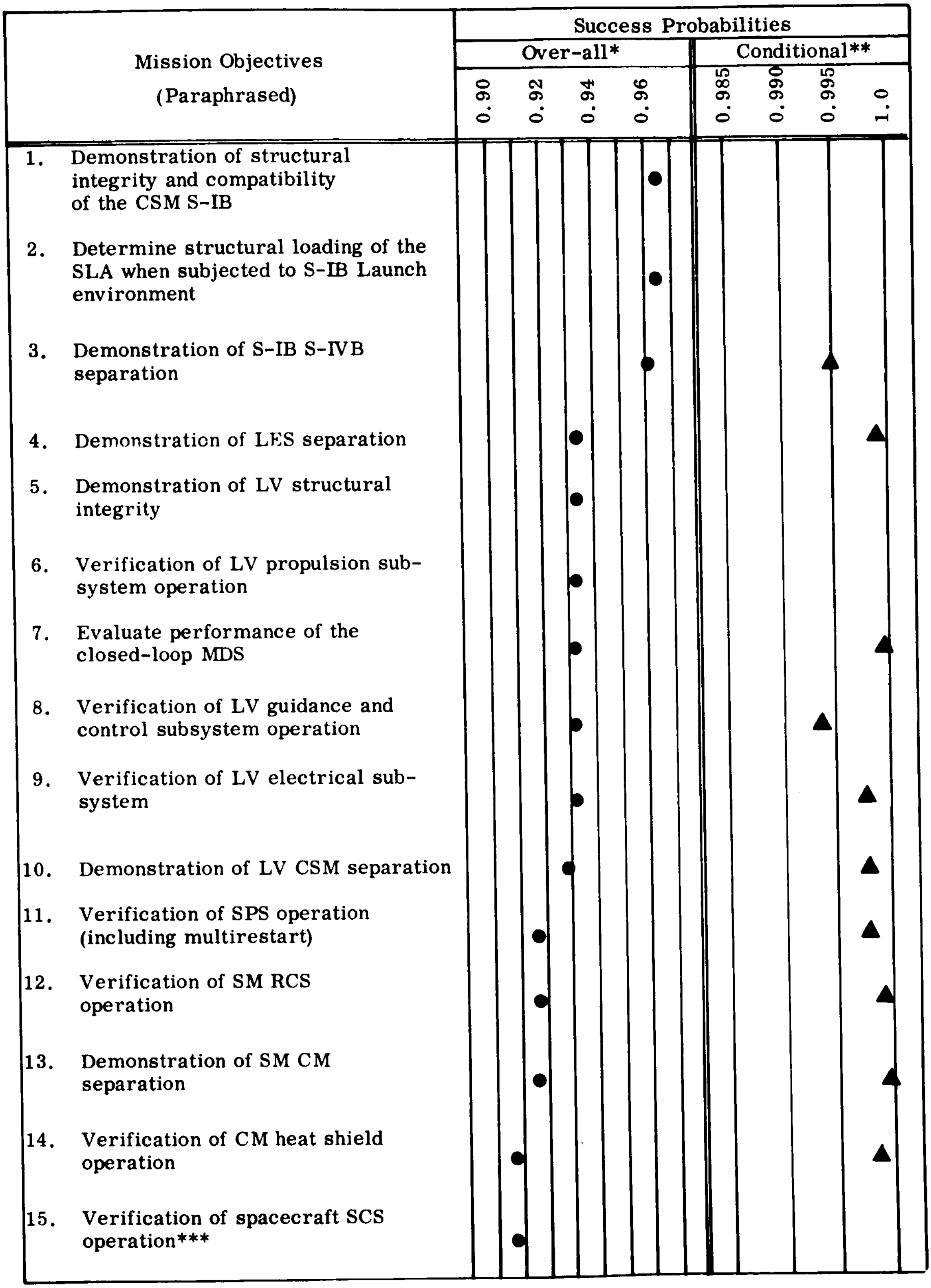
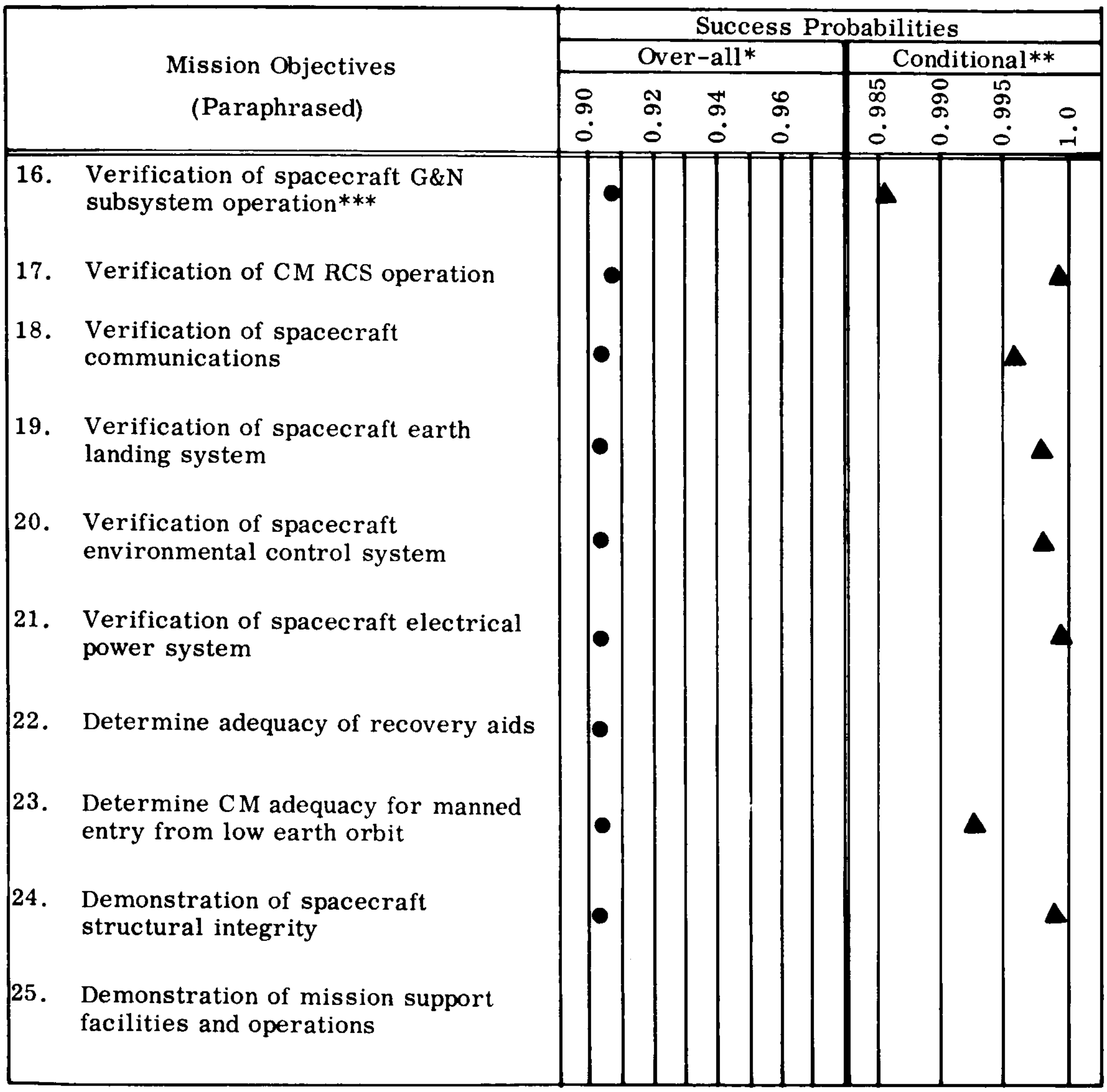


Figure 1-8. Apollo-Saturn 202 Mission Objective Predictions (Sheet 1 of 2)



* Including the effects of all phases of the flight mission required through the completion of each objective.
** Providing the mission has proceeded to the point where accomplishment of the particular objective has been started.
***Conditional probability is shown for combination of SCS and G&N.

Figure 1-8. Apollo-Saturn 202 Mission Objective Predictions (Sheet 2 of 2)

Using Launch Escape System*

Event	Elapsed Time from Liftoff (Hours: Minutes: Seconds)
Initiation (Worst Case)	00:02:50
Deploy Canards	00:03:01
Jettison LES	00:03:04
Jettison Apex Cover	00:03:05
Earth Impact	00:07:34
Recovery (Maximum)	48:00:00

* A contingency using the Launch Escape System as power for separation can be initiated automatically by the Closed-Loop Malfunction Detection System (or by a back-up command from the ground) any time between liftoff and 22 seconds after separation of the first stage at flight times between 00:00:00 and 00:02:50.

Using Service Propulsion System**

Event	Elapsed Time from Liftoff (Hours: Minutes: Seconds)
Initiation (Worst Case)	00:10:19
SPS Ignition	00:10:22
SPS Cutoff	00:10:32
SM-CM Separation	00:11:47
Earth Impact	00:27:59
Recovery (Maximum)	48:00:00

** A contingency using the Service Propulsion System as power for separation can be initiated by command from the ground any time from Launch Escape System jettisoning until the spacecraft separates from the S-IVB at flight times between approximately 00:03:00 and 00:10:19.

Figure 1-9. Apollo-Saturn 202 Profiles for Contingencies

The spacecraft supporting ground tests, Figure 1-4, are running slightly behind, but projection for the 202 mission appears to be that all tests will be completed prior to flight.

1.1.4 APOLLO-SATURN 203 MISSION

1.1.4.1 Configuration

The basic configuration difference between the Apollo-Saturn 202 and 203 launch vehicles lies in the changeover to thin-wall fuel and oxidizer tanks in the S-IB stage. The payload portion of the Apollo-Saturn 203 flight will consist only of a shroud rather than of a Command and Service Module.

1.1.4.2 Mission Profile/Mission Objectives

A primary objective of Apollo-Saturn 203 differs from that of the 201 and 202 missions. While Apollo-Saturn 201 and 202 missions are planned to develop the launch vehicle and spacecraft, the primary objective of mission 203 will be the experiment of liquid hydrogen containment in near zero-g environment, checkout of S-IVB and IU in orbit, and mission support facilities operation.

The mission plan for Apollo-Saturn 203 calls for a 100-nautical-mile circular orbit with no recovery.

The S-IVB-203 will enter orbit with 18,000 pounds of liquid hydrogen remaining in its tanks.

The profile for the Apollo-Saturn 203 mission, with major events and phase divisions applicable to modeling activities, is shown in Figure 1-10.

The mission profile and objectives will be reviewed and detailed during the next quarter when the applicable OMSF and MSFC Flight Mission Directives are issued.

1.1.4.3 Ground Support Test

The 70-inch fuel tank test program has been completed with preliminary analysis of the test results indicating that the fuel tank withstood 140 percent design limit load without sustaining excessive yield or failure.

Preparations are continuing for tests on the 70-inch LOX and 105-inch LOX tanks.

1.1.4.4 Reliability Prediction Plans

Compilation of predictions supplied by contractors for the Apollo-Saturn 203 mission will be made during the next quarter, and an over-all prediction for mission success will be made based upon these inputs.

Events	Elapsed Time (Hours: Minutes: Seconds)	Subphase Number*	Subphase Time in Seconds
Start Countdown		1	---
Liftoff, Hold Down Release	00:00:00	2	146.3
S-IB Engines Cutoff	00:02:26.3	3	0.8
S-IB/S-IVB Separation	00:02:27.1	4	1.6
S-IVB Engine Operating	00:02:28.7	5	299.8
S-IVB Engine Cutoff (Orbit Insertion)	00:07:28.5	6	0.1
LOX Ullage Thrust Control System Active	00:07:28.6	7	89.9
LH_2 Continuous Vent System Active	00:08:58.5	8	6.0
LOX Ullage Thrust Control System Deactivated	00:09:04.5	9	5,291.0
LOX Ullage Thrust Control System Active	01:36:15.5	10	2.0
LH_2 Continuous Vent System Deactivated	01:36:17.5	11	334.0
Engine Thrust Chamber Chilldown Active	01:41:51.5	12	15.0
Engine Thrust Chamber Chilldown Deactivated LH_2 Continuous Vent System Active	01:42:06.5	13	2.0
LOX Ullage Thrust Control System Deactivated	01:42:08.5	14	5,136.0
Engine Thrust Chamber Chilldown Active	03:07:44.5	15	9.0
LH_2 Continuous Vent System Deactivated	03:07:53.5	16	6.0
Engine Thrust Chamber Chilldown Deactivated	03:07:59.5	17	301.0
LH_2 Continuous Vent System Active	03:13:00.5	18	60.0
LOX Ullage Thrust Control System Active	03:14:00.5	19	5,295.0
LH_2 Nonpropulsive Vent System Active	04:42:15.5	20	60.0
LH_2 Nonpropulsive Vent System Deactivated	04:43:15.5	21	88.0
LH_2 Nonpropulsive Vent System Active	06:11:15.5	22	60.0
LH_2 Nonpropulsive Vent System Deactivated	06:12:15.5		
(End of Mission)			

*A subphase extends from an event to the next event

Figure 1-10. Apollo-Saturn 203 Mission Profile

1.2 S-IB STAGE

1.2.1 GENERAL

1.2.1.1 Milestones

Milestones necessary to monitor the S-IB Stage Reliability and Quality Assurance Program are shown in Figure 1-11. In general, the documentation identified provides the data required to establish the S-IB Stage Reliability and Quality Assurance status.

a. Reliability assessments for the S-IB-1 stage and its six subsystems were prepared by CCSD and forwarded to MSFC for inclusion in the Pre-flight Readiness Review at MSFC on 14 and 15 December.
b. Changeover of the number 1 fuel tank for S-IB-1 at KSC was inspected and approved.
c. Eighty-eight percent of the checkout of the S-IB-2 stage was completed.

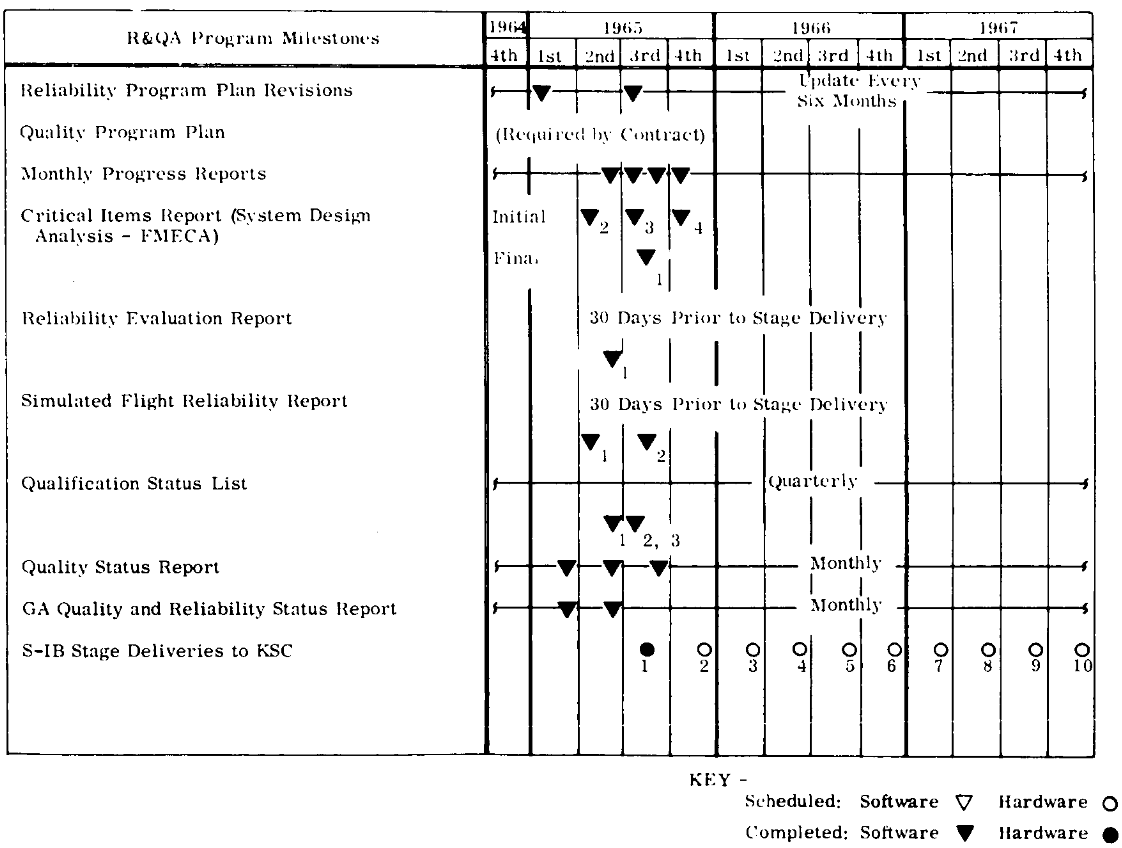
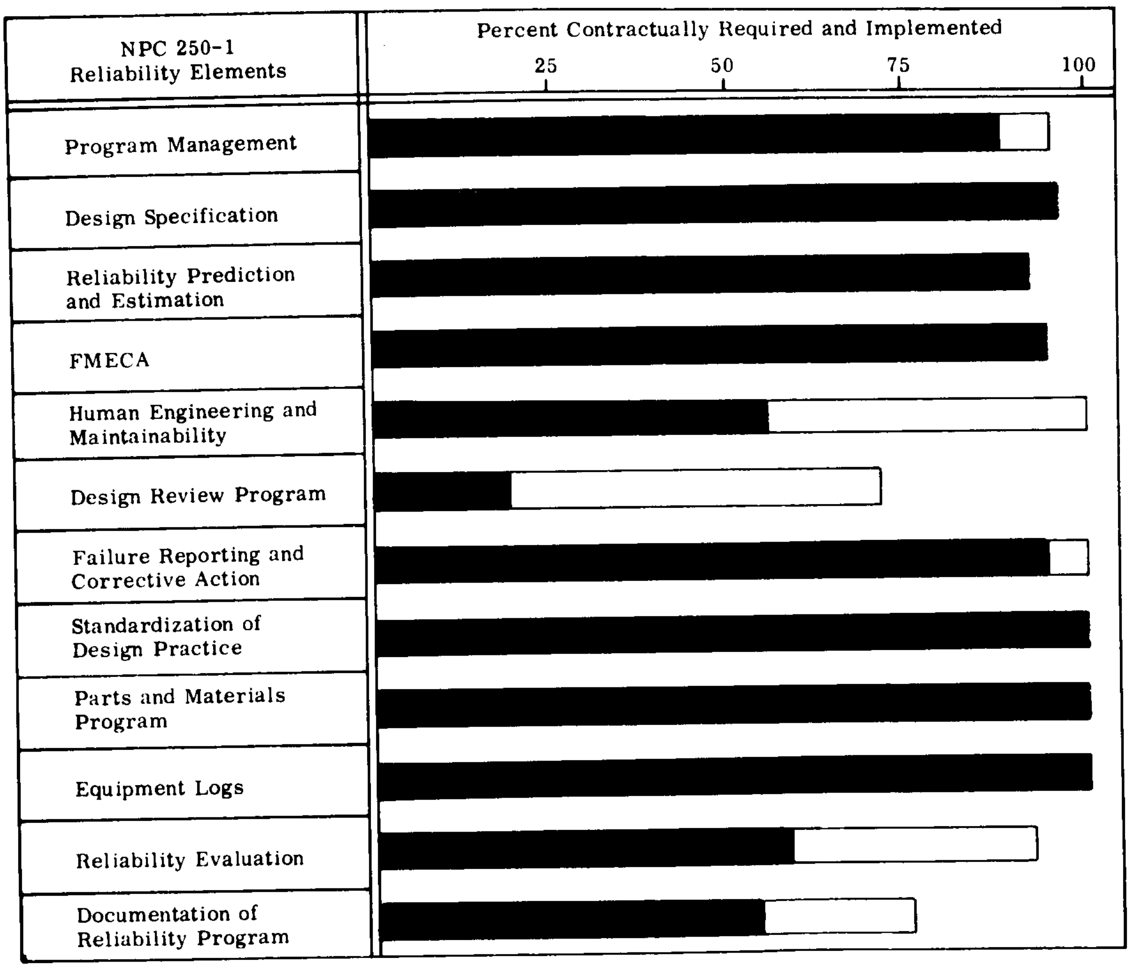


Figure 1-11. S-IB Stage Reliability and Quality Assurance Milestones

1.2.1.2 Reliability Program

A continuation of the reliability assurance evaluation was performed by MSFC on the S-IB stage. The evaluation compared the degree that NPC 250-1 reliability elements were contractually required and the degree to which they have been implemented (see Figure 1-12).

There was a five percent reduction in the implementation of the program management element because the current Reliability PERT System does not provide the detail necessary for management control and scheduling of the program. There were also slight reductions in percent implementation of the human engineering, design review, failure reporting, and documentation elements because various reports were not being made available for review.



Contractor CCSD

Contractor No. NAS8-4016

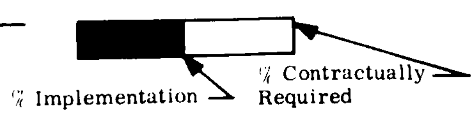


Figure 1-12. S-IB Stage Reliability Assurance Evaluation Based on NPC 250-1

1.2.2 RELIABILITY ENGINEERING

1.2.2.1 Design

The effect on Saturn IB vehicles due to the 205K H-1 engine uprating was analyzed. Some changes in compartment venting characteristics may be required due to trajectory changes.

Performance analyses concerning engine-out, abort, and alternate mission for vehicle SA-203 were published by CCSD.

1.2.2.2 Redundancy and Trade-off Studies

Proposed rerouting of LOX bubbling line 60C10645 to avoid human damage was approved by NASA. This change will be effective on S-IB-7 and subsequent stages.

1.2.2.3 FMECA

An initial issue of the failure mode and effect analysis for the S-IB-4 was performed by CCSD. The ten most critical items for the S-IB-1, S-IB-3, and S-IB-4 are shown on Figure 1-13. The initial report for the S-IB-2 stage, issued April 1965, did not present an analysis of the critical items on the same basis as did the later reports on the other stages. For example, the critical items that ranked third, the feedback transducer, and fifth, the servo valve, were previously analyzed as part of an assembly, and there was insufficient data at that time to analyze the switch selector assembly, the second item.

1.2.2.4 Mathematical Models

Reliability assessments for the S-IB-1 stage and its subsystems utilizing the reliability mathematical model for 10,000 simulated flights were issued by CCSD on 19 November 1965 and forwarded to MSFC.

During the reporting period, the functional reliability elements for S-IB-4 were completed for use in the reliability mathematical model.

1.2.2.5 Goals and Predictions

A trend of mission success predictions in relation to the goal for the S-IB stage is displayed on Figure 1-14. Preflight stage and subsystem reports for the S-IB-1 stage were issued by CCSD. These reports were used to support the Saturn IB Program Office's input to the flight readiness review for the Apollo-Saturn 201 mission.

The demonstrated reliability trend of the H-1 engine is plotted on Figure 1-15. Engine reliability is based on the last one hundred equivalent full-duration tests.

1.2.3 TEST PROGRAM

1.2.3.1 Ground Support Test

During September and October, 37 failures have been identified on the S-IB-1 stage bringing the total failures to 215 since manufacturing checkout. As shown on Figure 1-16, control action is pending on 29 failures. These failures were reported from KSC prelaunch and five are classified as critical. MSFC resolved all outstanding failures which occurred prior to delivery to KSC. The failure summaries for S-IB-2 and S-IB-3 are shown on Figures 1-17 and 1-18, respectively.

The 70-inch fuel tank test program has been completed with preliminary analysis indicating that the tank successfully withstood 140 percent design limit load without sustaining excessive yield or failure.

Fin assembly, part number 60C30650, completed vibration and qualification testing during the reporting period.

Item	Subsystem	Criticality Ranking by Flight Stage			
		S-IB-1	S-IB-2	S-IB-3	S-IB-4
Gas Turbine	H-1 Engine	1	Note: See Text	1	1
Switch Selector Assembly	Sequencing	2		2	2
Feedback Transducer	H-1 Engine Hydraulic	3		3	3
GG Control Valve	H-1 Engine	4		4	4
Servo Valve	H-1 Engine Hydraulic	5		5	5
Prevalve Control Valve	H-1 Engine	6		6	6
Turbo Pump and Gearbox Assembly	H-1 Engine	7		7	7
LOX Replenishing Valve	LOX Fill, Drain and Replenish	8		8	8
Regulator	Control Pressure	9		9	9
LOX Fill and Drain Valve	LOX Fill, Drain and Replenish	10		10	10

Items Dropped from Preceding List:

Rank	Item

Figure 1-13. S-IB Stage Ten Most Critical Items

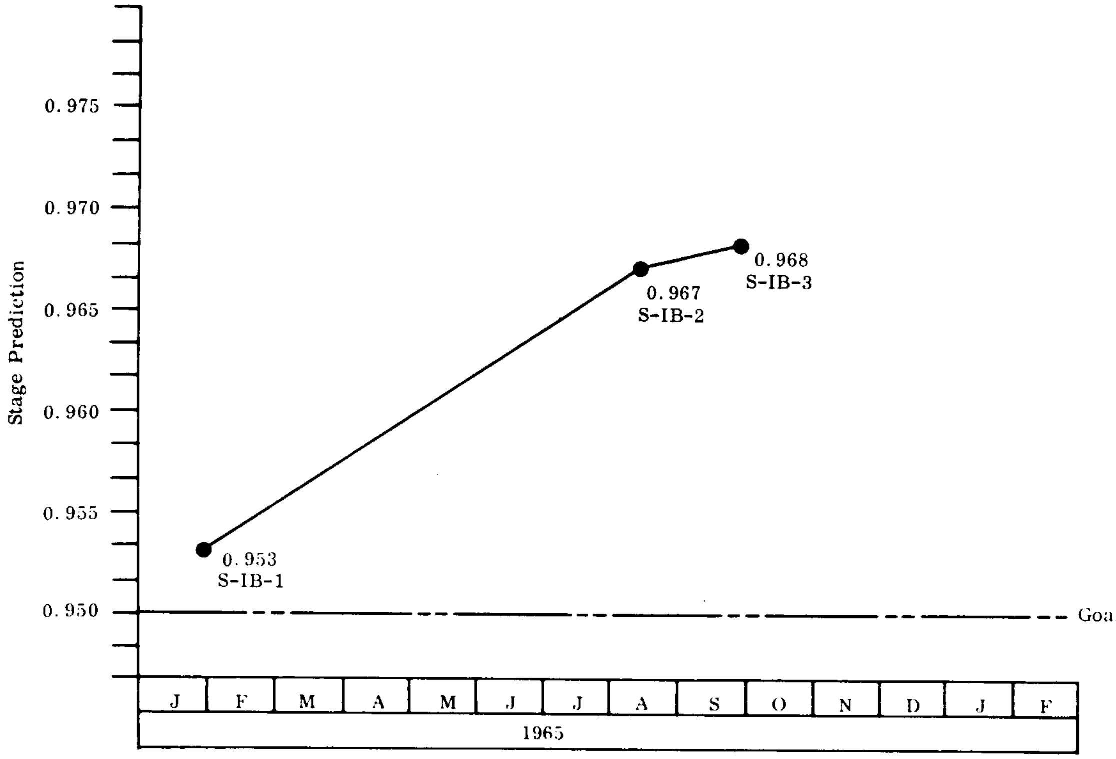


Figure 1-14. S-IB Stage Reliability Trend (Mission Success)

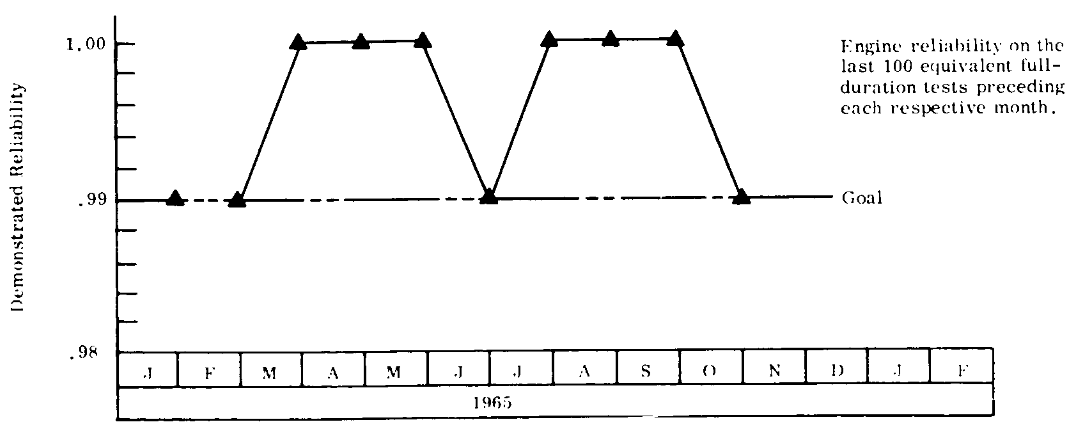


Figure 1-15. H-1 Engine Demonstrated Reliability Trend (Mission Success)

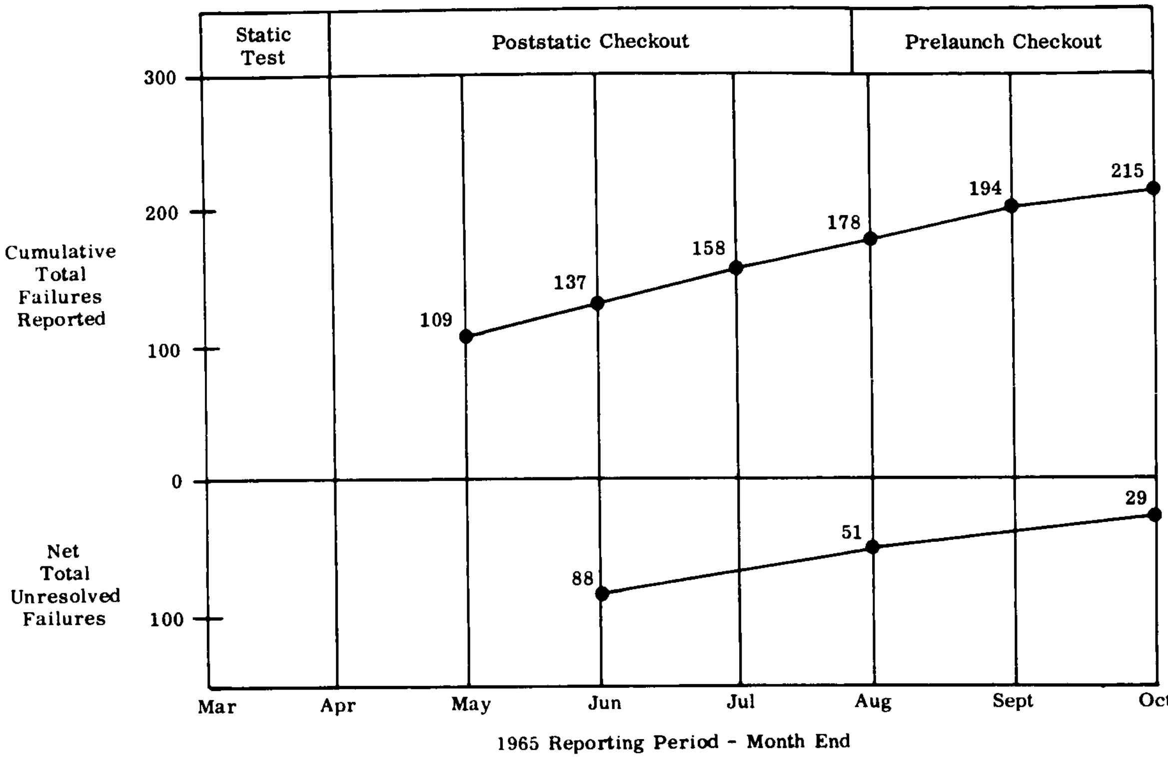


Figure 1-16. S-IB-1 Stage Total Failure Summary and Trend

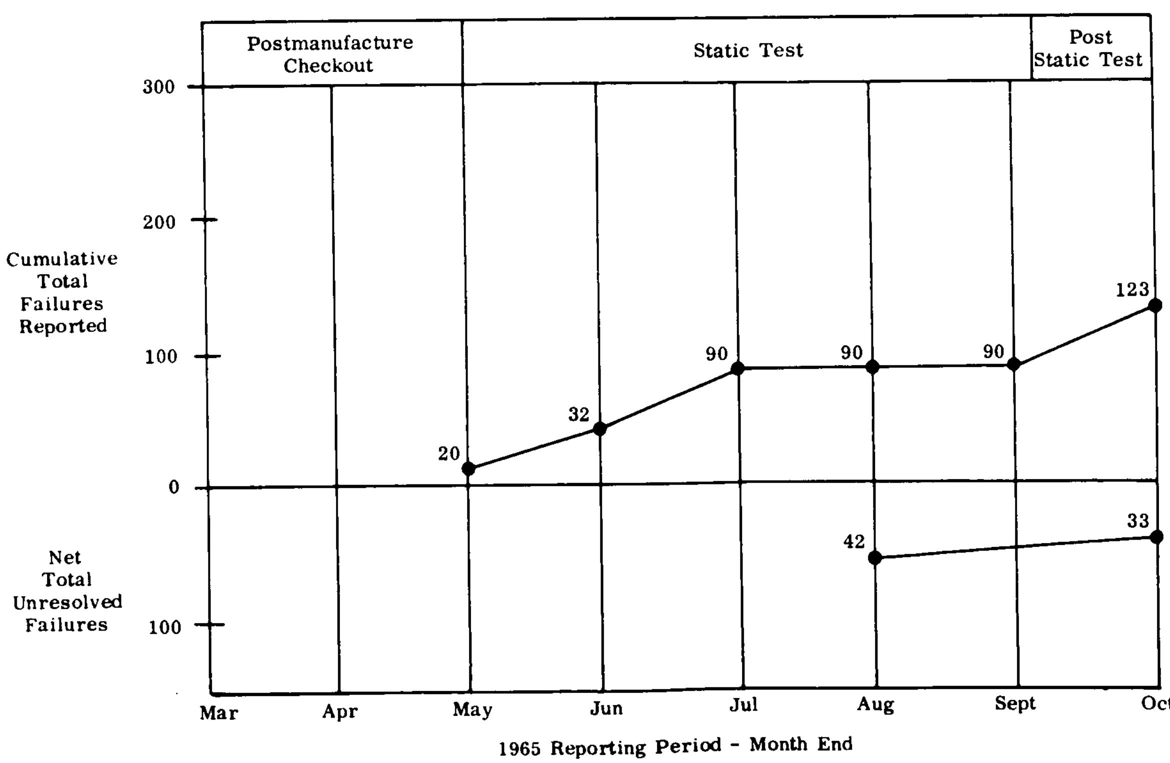


Figure 1-17. S-IB-2 Stage Total Failure Summary and Trend

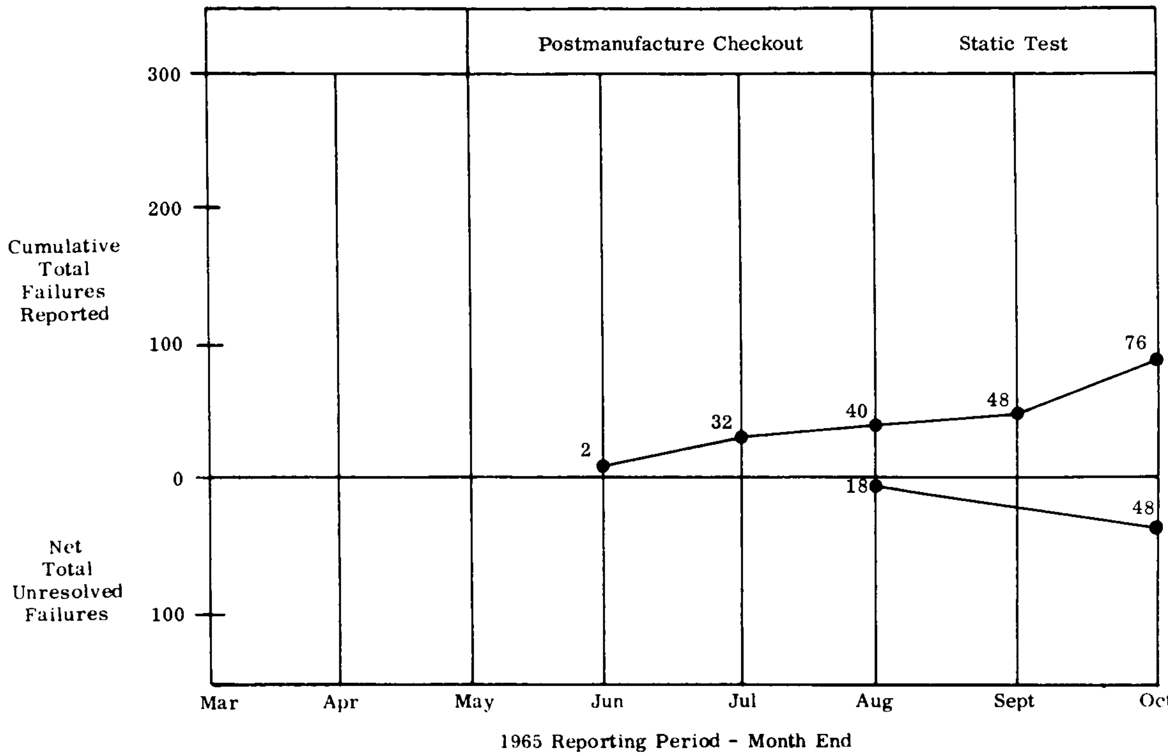


Figure 1-18. S-IB-3 Stage Total Failure Summary and Trend

1.2.3.2 Qualification Test

Figure 1-19 shows the total component qualification status for the S-IB-1 stage. While there is a total of only four components behind schedule, there are seven flight-critical items remaining to be qualified. These items are:

a.	Fuel vent line (20C00051)	Failed vibration testing - waiver required for S-IB-1.
b.	Hydraulic package (20C85053)	Failed vibration testing - waiver required for S-IB-1.
c.	Upper turbine exhaust (20C00013)	Cracks developed during vibration testing - waiver required for S-IB-1.
d.	Fuel interconnect (20C00052)	Failed vibration testing - new vibration levels established and retest in progress.
e.	Fuel manifold (20C00049)	Failed vibration testing - fix being applied - component to be retested.
f.	GOX manifold assembly (60C20111)	Failed vibration testing - test set-up being revised and component will be retested.
g.	GN control pressure system (60C20458)	Failed during vibration testing - line size to be changed and system to be retested.

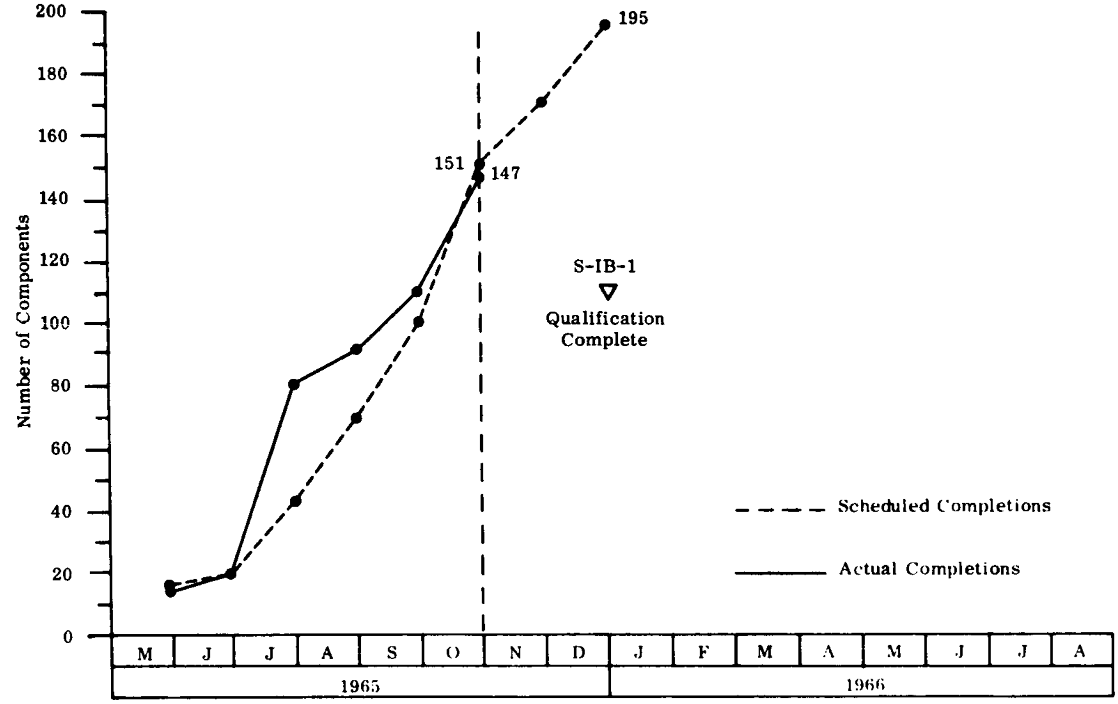


Figure 1-19. S-IB-1 Stage Total Component Qualification

1.3 S-IVB STAGE

1.3.1 GENERAL

1.3.1.1 Reliability Milestones

The schedule for S-IVB stage reliability milestones is shown in Figure 1-20. The milestones shown are keyed to hardware delivery dates with the supporting documentation providing the data required to establish the S-IVB stage reliability program status.

Major accomplishments during the reporting period include:

a. Completion of the reliability assessment for S-IVB-201 utilizing test data to replace generic failure rates for 33 percent of the total flight critical items.
b. Delivery of S-IVB-203 to Sacramento Test.
c. Completion of Saturn IB facility checkout using the S-IVB 200F vehicle.

1.3.1.2 Reliability Program

The MSFC Monthly Reliability Assurance Evaluation survey results indicate the degree that contractors are implementing contractually required elements of NPC 250-1.

Reliability elements that show increased implementation during this report period are as follows:

S-IVB Stage	Percent
Failure Reporting and Corrective Action	77 to 82
Parts and Materials	68 to 72
Reliability Evaluation	58 to 78
Documentation of Reliability Program	68 to 76

J-2 Engine	
Design Specification	80 to 82
Reliability Prediction and Estimation	24 to 29
FMECA	33 to 55

The reliability audit results through 9 November 1965, for S-IVB and J-2 programs are shown in Figures 1-21 and 1-22.

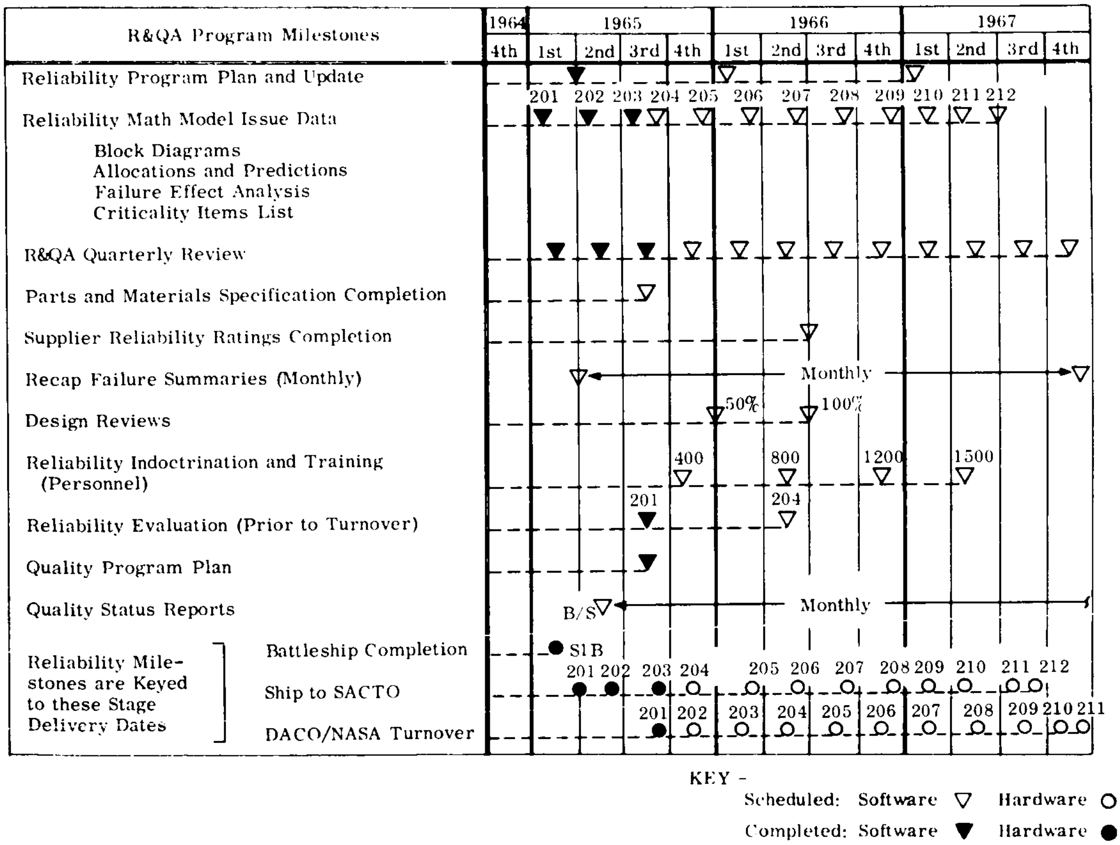
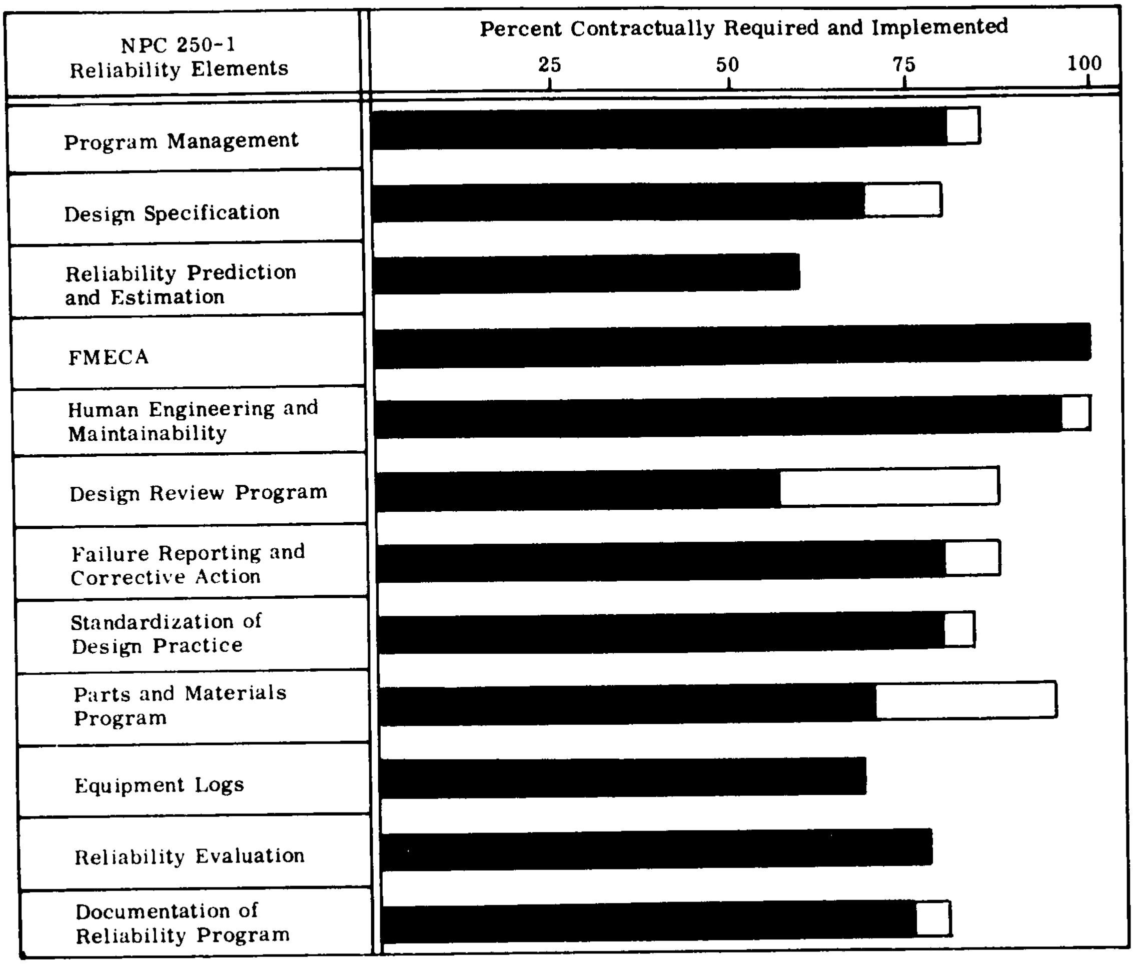


Figure 1-20. Saturn IB S-IVB Stage Reliability and Quality Assurance Milestones



Contractor Douglas

Contractor No. NAS7-101

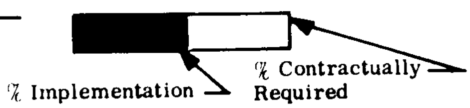
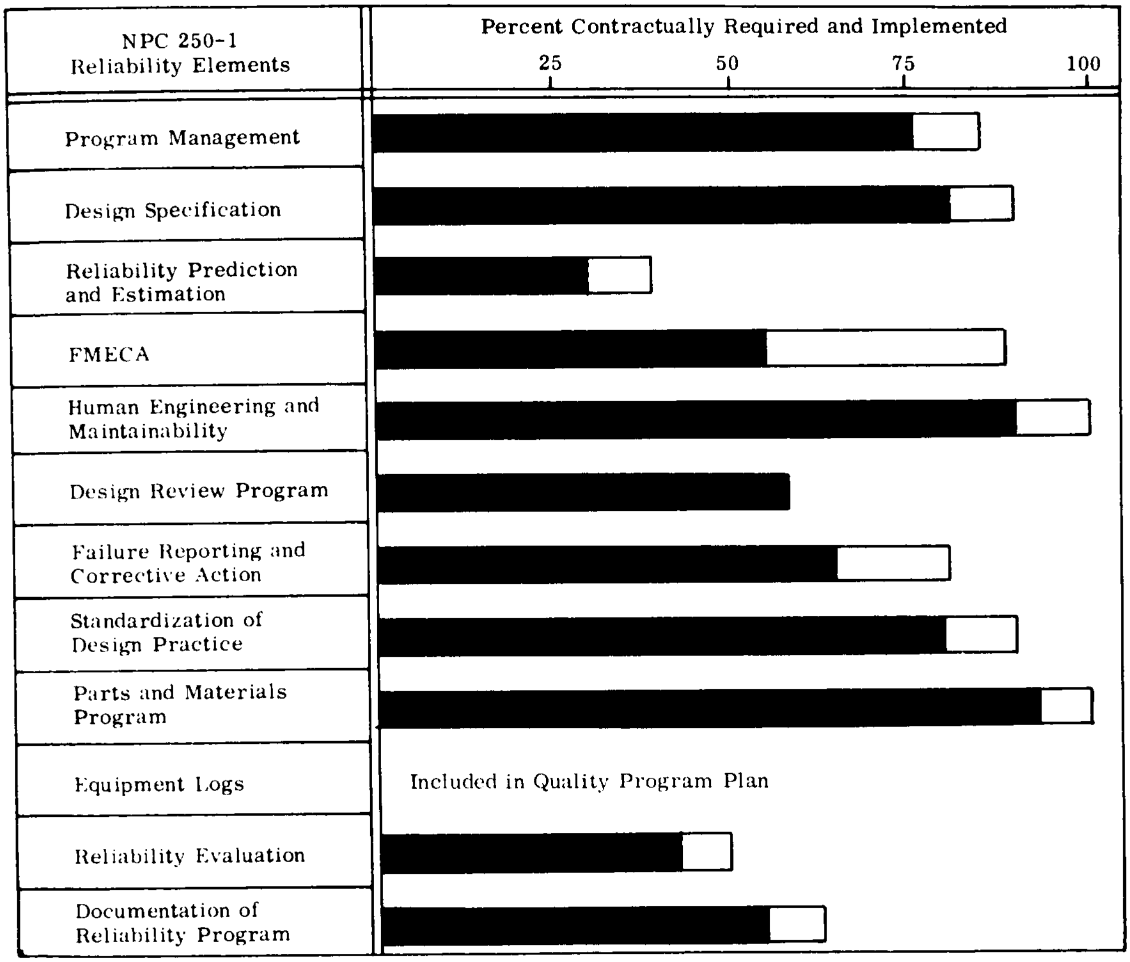


Figure 1-21. Saturn IB/V S-IVB Stage Reliability Assurance Evaluation Based on NPC 250-1



Contractor Rocketdyne

Contractor No. NAS8-19

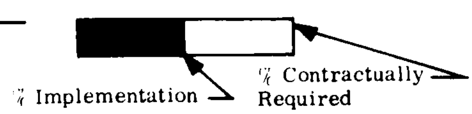


Figure 1-22. J-2 Engine Reliability Assurance Evaluation Based on NPC 250-1

1.3.2 RELIABILITY ENGINEERING

1.3.2.1 Design

Approved Engineering Change Proposal (ECP's) and Scope Changes (SC's) to the S-IVB stage are incorporated in S-IVB Reliability Engineering Models. The S-IVB-202 model was updated with seventeen ECP's and SC's. The S-IVB-203 engineering model lists the same ECP's and SC's as does the 202. The reliability prediction for S-IVB-202 and 203 is the same (0.97) (see Figure 1-23).

1.3.2.2 Redundancy and Trade-Off Studies

Strength evaluation of the S-IVB-201 skirts and interstage for the AS-201 mission have been completed and transmitted to MSFC. As noted in the strength evaluation, one area of the S-IVB-201 stage is under strength for AS-201 mission loads.

A thermal stress analysis was conducted on the main tunnel forward fairing for S-IVB-201 maximum temperatures. Temperature over the forward fairing will be restricted to 450°F maximum. A thermal-protective coating will be required.

1.3.2.3 FMECA

FMECA's have been completed for S-IVB-201, 202, and 203. The ten most critical items based on the reliability analyses and criticality ranking are listed in Figure 1-24.

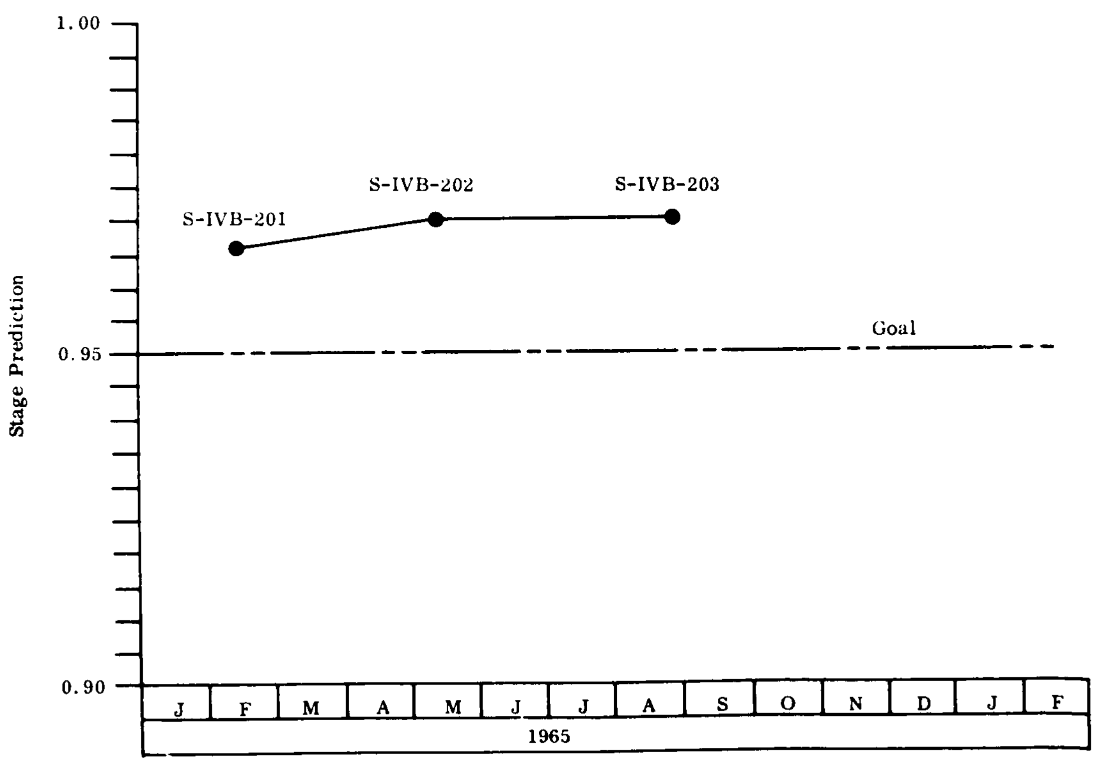


Figure 1-23. Saturn IB S-IVB Stage Reliability Trend (Mission Success)

Item	Subsystem	Criticality Ranking by Flight Stage			
		S-IVB-201	S-IVB-202	S-IVB-203	
J-2 Engine (GFE)	Thrust	2	1	1	
Switch Selector (GFE)	Electrical Control	1	2	2	
Motor, Retro Rocket (4)	Reverse Thrust, Lower Stage	22	3	3	
Actuator Assembly, Hydraulic (2)	Hydraulic	5	4	4	
Module, Actuation Control (7)	Pneumatic Control	4	6	5	
Mounting Assembly Sequencer	Electrical Control	7	5	6	
Valve Propellant Tank Shutoff	LH_2 Feed and Chilldown	18	9	7	
Hydraulic Pump, Thermal Isolator Assembly	Hydraulic	10	7	8	
Pump, Hydraulic, Auxiliary Motor Driven	Hydraulic	12	10	9	
Pump, LH_2 Auxiliary Motor Driven Chilldown	LH_2 Feed and Chilldown	9	15	10	

Items Dropped from Preceding List:

Rank	Item
8	Power Distribution Mounting Assembly

Figure 1-24. Saturn IB S-IVB Stage Ten Most Critical Items

1.3.2.4 Mathematical Models

Douglas Aircraft Company (DAC) has changed the title of the S-IVB reliability model report from "Reliability Mathematical Model" to "Reliability Engineering Model" for S-IVB-203 and those subsequent. This report contains the reliability block diagrams, failure effect analyses, numerical reliability allocations, predicted probabilities of no-stage-loss; list of flight critical items; and a summary that associates mission or vehicle loss with a particular failure type/mode.

1.3.2.5 Apportionments, Predictions, and Assessments

DAC assessed the S-IVB stage to have a reliability (probability of no-stage-loss) of 0.962, based upon the 50 percent confidence failure rates of those flight critical items (FCI's) with sufficient data for evaluation. Of the 113 total FCI's on the S-IVB stage, data for 89 was evaluated for inclusion in the assessment report. Data for 37 of these 89 items passed the criteria for replacement of prediction failure rate data. The remaining 52 were deemed to have insufficient test data to replace the prediction failure rate information. There were 24 FCI's for which no test failure rate data was available for consideration in the assessment.

1.3.3 TEST PROGRAM

1.3.3.1 Ground Support Tests

A total of sixteen failures was reported on the S-IVB-201 stage during the post-static and prelaunch checkout phases. A net total of eleven unresolved failures remain. Of the eleven unresolved failures, ten have not been assigned criticality rankings or were rated as noncritical (see Figure 1-25). The other unresolved failure, propellant utilization feed through connector, has been rated "major," because an open circuit can result in possible loss of the LOX P.U. signal. It is anticipated that all of the eleven open failure problems will be resolved prior to the flight readiness review. The failure summary trends for S-IVB-202 and S-IVB-203 are shown on Figures 1-26 and 1-27, respectively.

Simulated countdown and acceptance firing tests for S-IVB-202 were run on 3 November 1965, for three seconds and on 9 November 1965, for 307 seconds.

A delay in the completion of acceptance testing has caused the KSC shipping date for S-IVB-202 to slip to the last week in December 1965.

1.3.3.2 Qualification Test

Based on the status as of 31 October 1965, there are 27 components remaining to be qualified on the S-IVB-201 stage. Eleven of the 27 components are flight critical items and should be qualified prior to launch of SA-201 (see Figure 1-28).

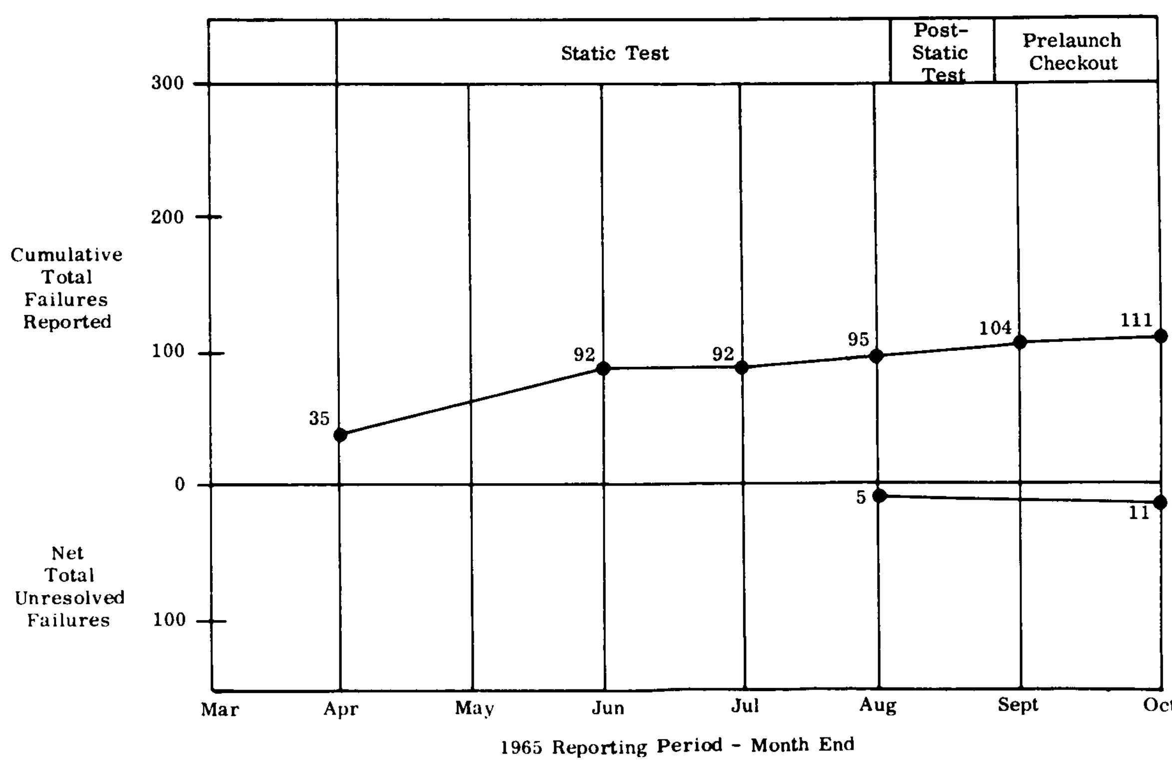


Figure 1-25. S-IVB-201 Stage Total Failure Summary and Trend

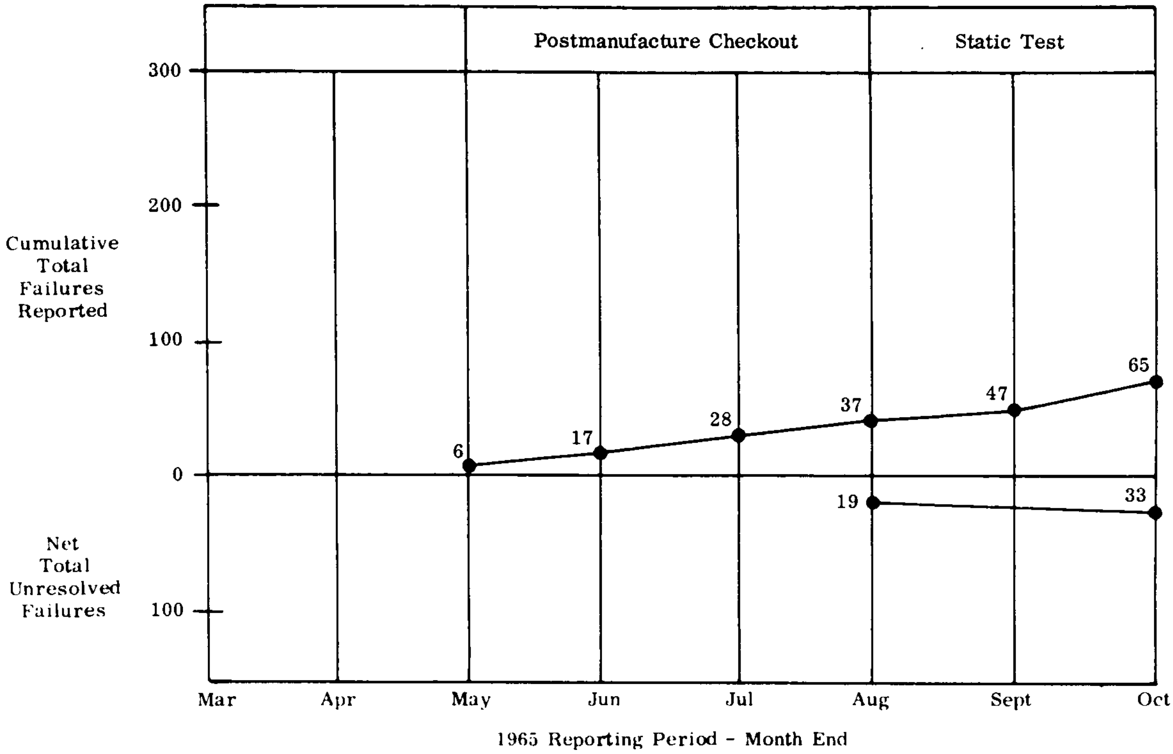


Figure 1-26. S-IVB-202 Stage Total Failure Summary and Trend

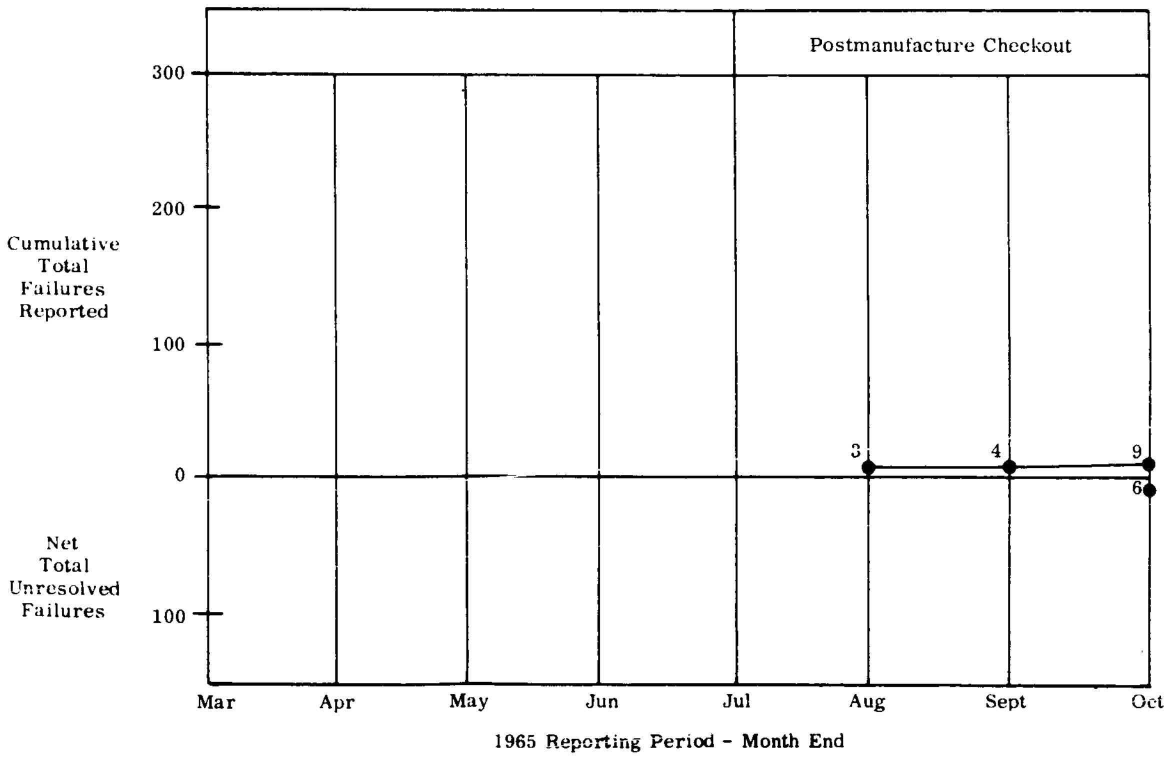


Figure 1-27. S-IVB-203 Stage Total Failure Summary and Trend

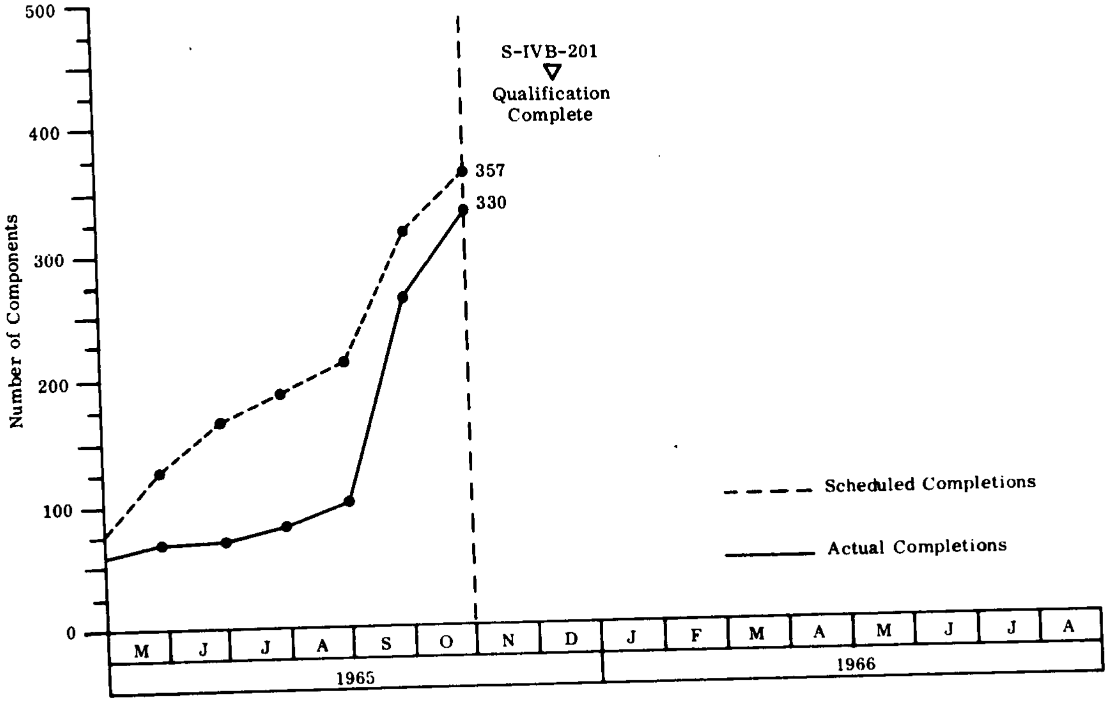


Figure 1-28. S-IVB-201 Stage Total Component Qualification

1.3.4 QUALITY ASSURANCE

1.3.4.1 Quality Trends

Figure 1-29 shows the trend in percent of parts of J-2 engines discrepant at final assembly.

Figure 1-30 shows the trend in discrepancies/malfunctions on J-2 engines at electrical and mechanical inspection.

1.3.4.2 Quality Problems

S-IVB-201 arrived at KSC with several relatively serious discrepancies. These included (1) a common bulkhead wrinkle, (2) tank insulation debonding, and (3) high stress in the LH_2 of LOX jamb welds with resulting cracks.

Low pins have been found on several occasions during the second electrical and mechanical inspection of J-2 harness assemblies. Potting of all interface harness connectors has been initiated effective with engine J-2048-55 and kits have been provided for earlier engines.

[redacted]

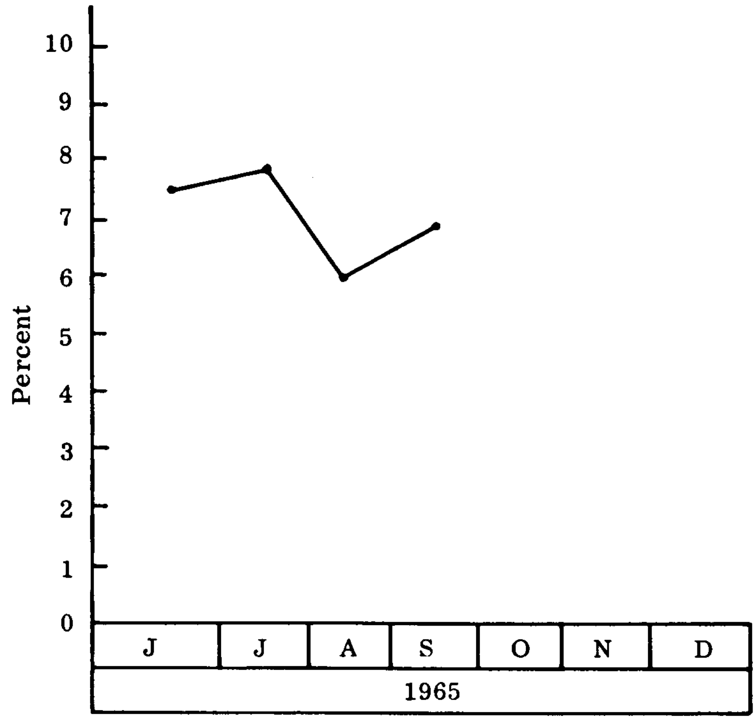


Figure 1-29. Percent of J-2 Engine Parts Discrepant at Final Assembly

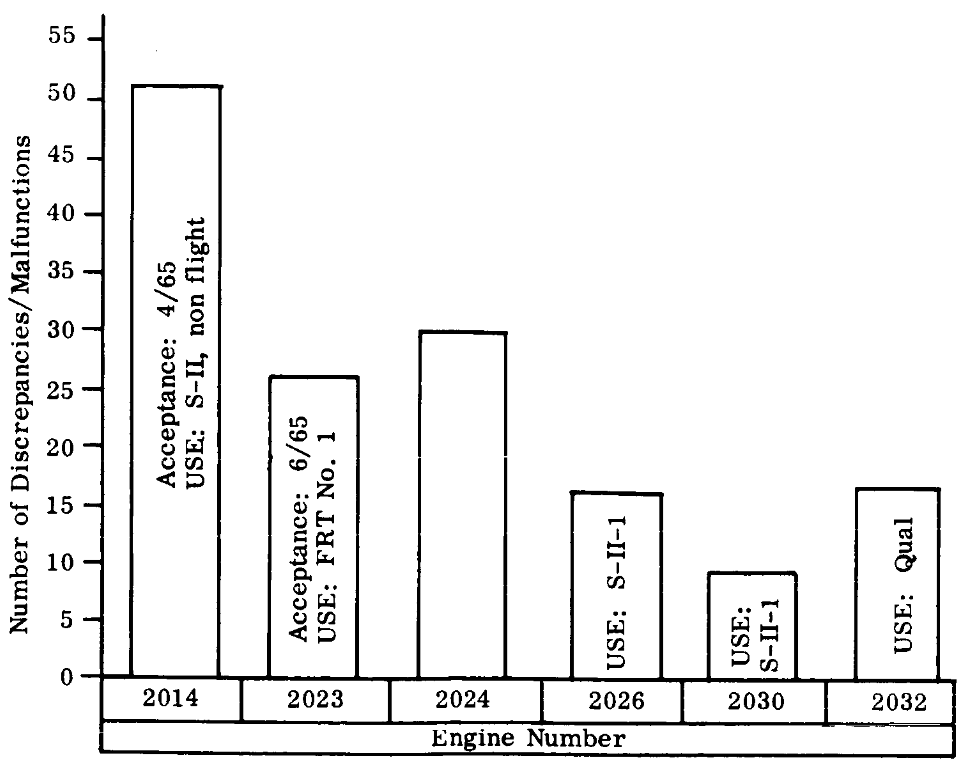


Figure 1-30. Discrepancies/Malfunctions at J-2 Engine E&M Inspections

1.4 S-IU STAGE

1.4.1 GENERAL

1.4.1.1 Milestones

The documentation resulting from the milestones shown in Figure 1-31 provides, in general, the basis for establishing the Saturn IB/V Instrument Unit reliability and quality status in relation to the Saturn IB delivery schedule.

The "Saturn IB/V Instrument Unit Reliability and Part Program Plan," IBM No. 65-382-0004H was released 1 October 1965. This is the first update of the plan.

In accordance with the MSFC directed change to contract NAS8-14000, dated 8 April 1965, IBM is to develop a handbook of IU component part failure rate data and their environmental "K" factors. This handbook shall be published by 1 January 1966, and updated quarterly through 1 January 1968.

The updated "General Test Plan" is being prepared and will be delivered to MSFC by 30 November. The scheduled delivery of 31 October could not be met because of conflicting effort to update the NPC 500-10 Impact Study for the Saturn IB/V Instrument Unit.

S-IU-201 was shipped 9 October and received 20 October at KSC.

1.4.1.2 Reliability Program

MSFC conducted its bimonthly reliability assurance evaluation on three Instrument Unit contractors during October. The results are shown in Figures 1-32 through 1-34.

Two program categories (reliability predictions and estimation, and design review program) were increased to 100 percent contractually required on contract NAS8-14000.

On contracts NAS8-11561 and -11562 one category (equipment logs) was increased to 100 percent contractually required. Three categories (program management, reliability prediction and estimation, and documentation of reliability program) were decreased in percent of implementation on contracts NAS8-11561 and -11562. The decreases were mainly due to lack of reliability information in required documentation. Most other categories indicated progress.

1.4.2 RELIABILITY ENGINEERING

1.4.2.1 Design

During the reporting period two significant design review meetings were conducted on Instrument Unit components by MSFC. These are (1) 810 multiplexer and (2) command decoder. A final report on the multiplexer will be completed by 1 November. The command decoder design review resulted in a contract go-ahead with Spacecraft, Inc., for 12 flight units. Investigation will be continued on the high-temperature circuit failures identified during tests following the engineering model checkout of the command decoder.

1.4.2.2 Redundancy and Trade-Off Studies

Replacement of the selector switch with the MOD II version has been delayed by the discovery of cracks in the metal film resistor after exposure to temperature cycling. Investigation is underway to identify the cause and to develop an action plan to preclude recurrence of this failure.

1.4.2.3 FMECA

The ten most critical items shown in Figure 1-35 are based on information supplied by IBM for the 201 flight readiness review. This information is in advance of the final S-IU-201 FMECA now estimated for release by mid-December 1965.

The updated "Reliability and Part Program Plan," dated 1 October 1965, includes the following schedule for FMECA's:

System	Preliminary	Final
S-IU-201	5/65 (completed)	11/65
S-IU-202	9/65	1/66
S-IU-203	11/65	3/66

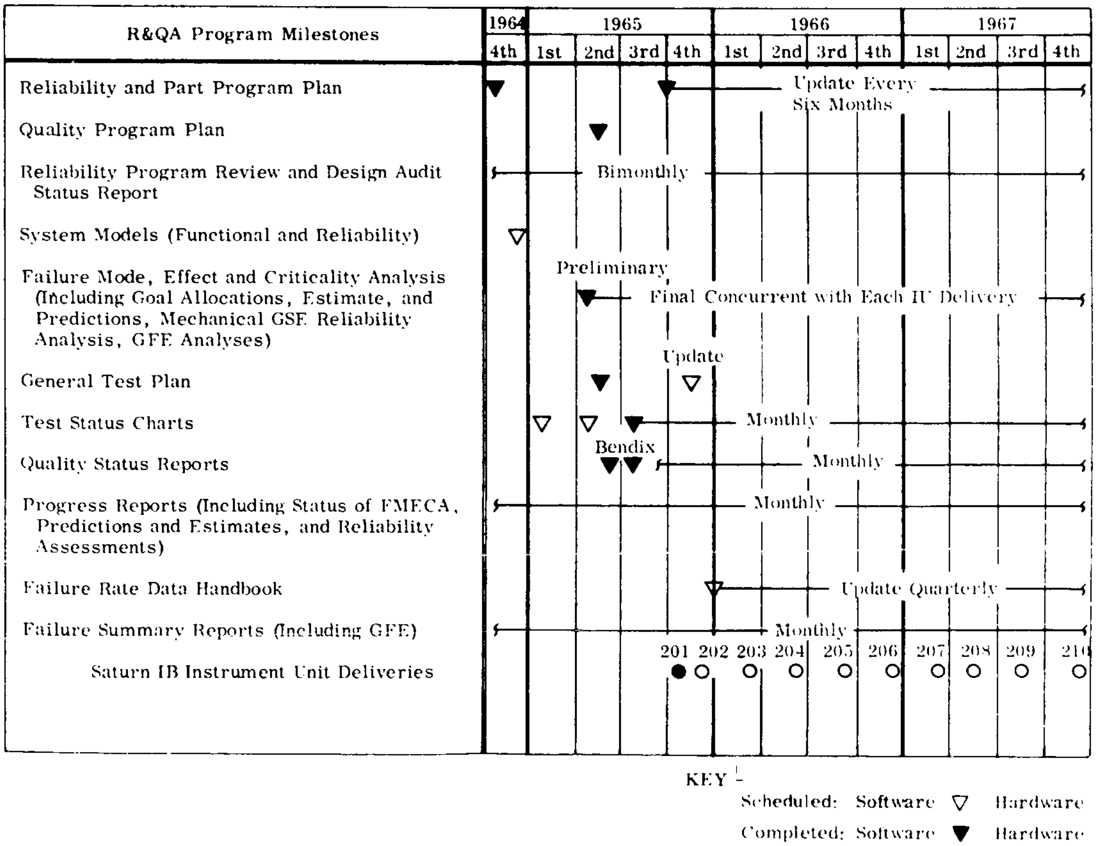
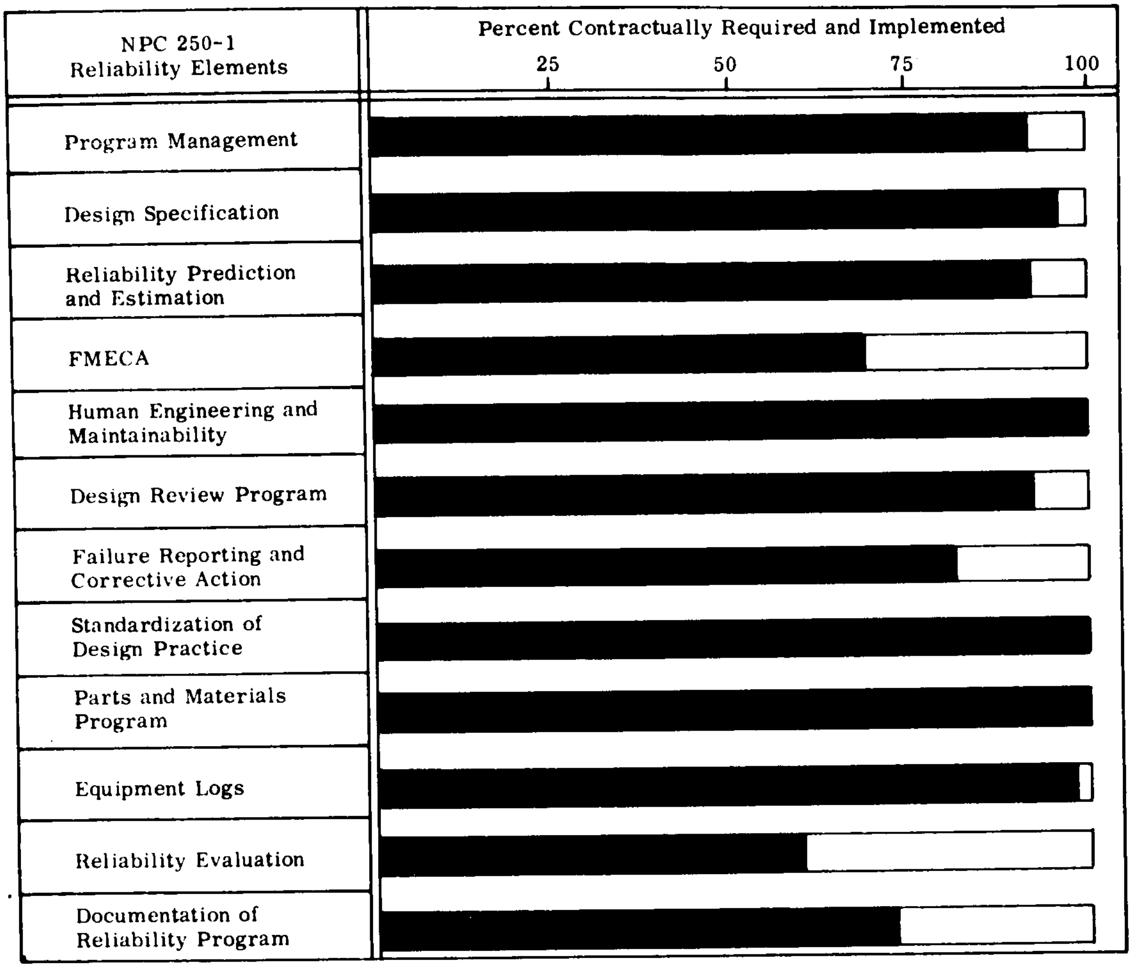


Figure 1-31. Saturn IB Instrument Unit Reliability and Quality Assurance Milestones



Contractor IBM, Huntsville

Contractor No. NAS8-14000

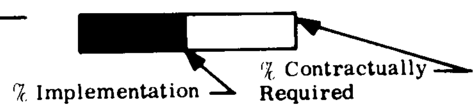


Figure 1-32. Saturn IB/V Instrument Unit Reliability Assurance Evaluation Based on NPC 250-1

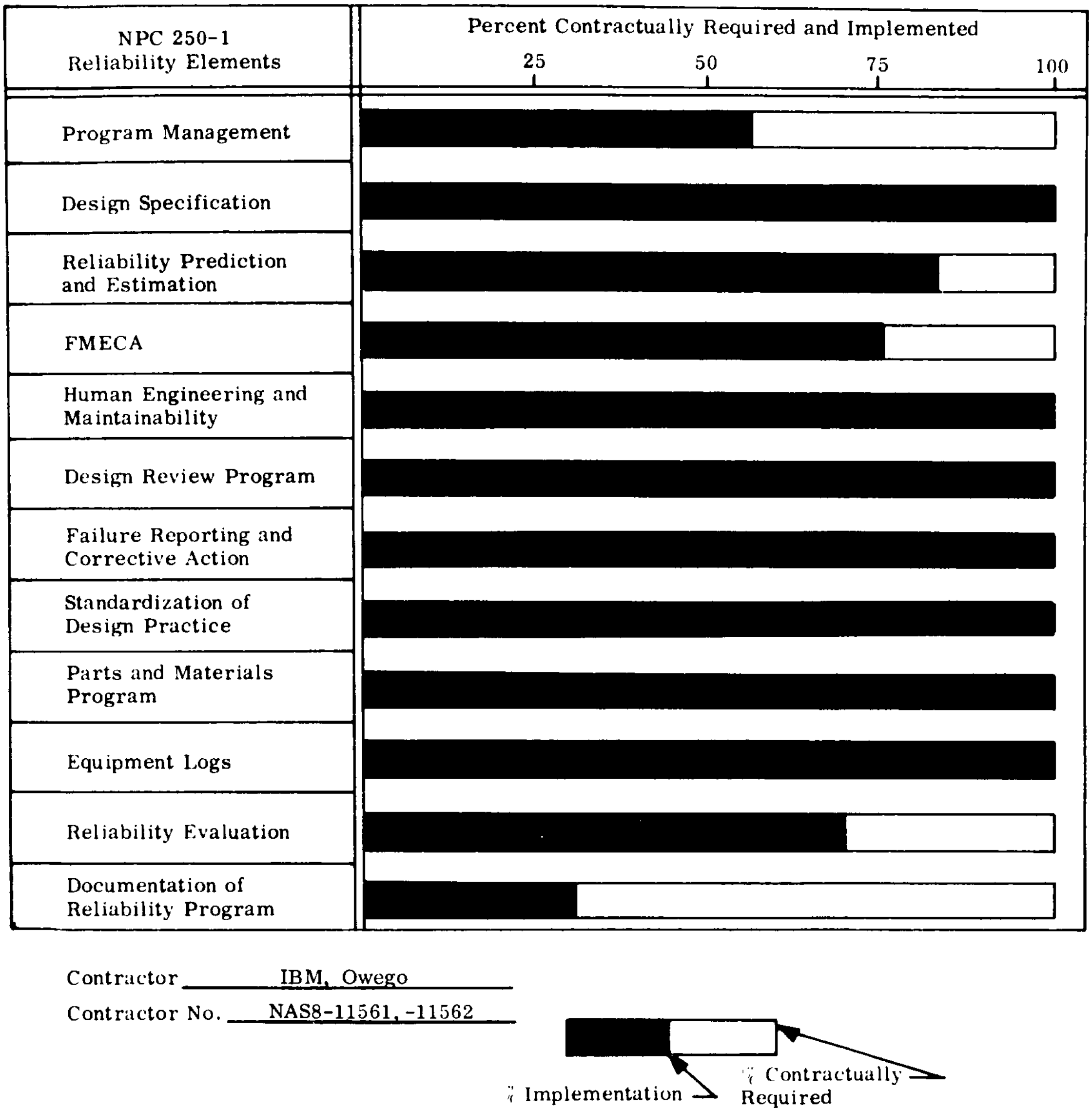
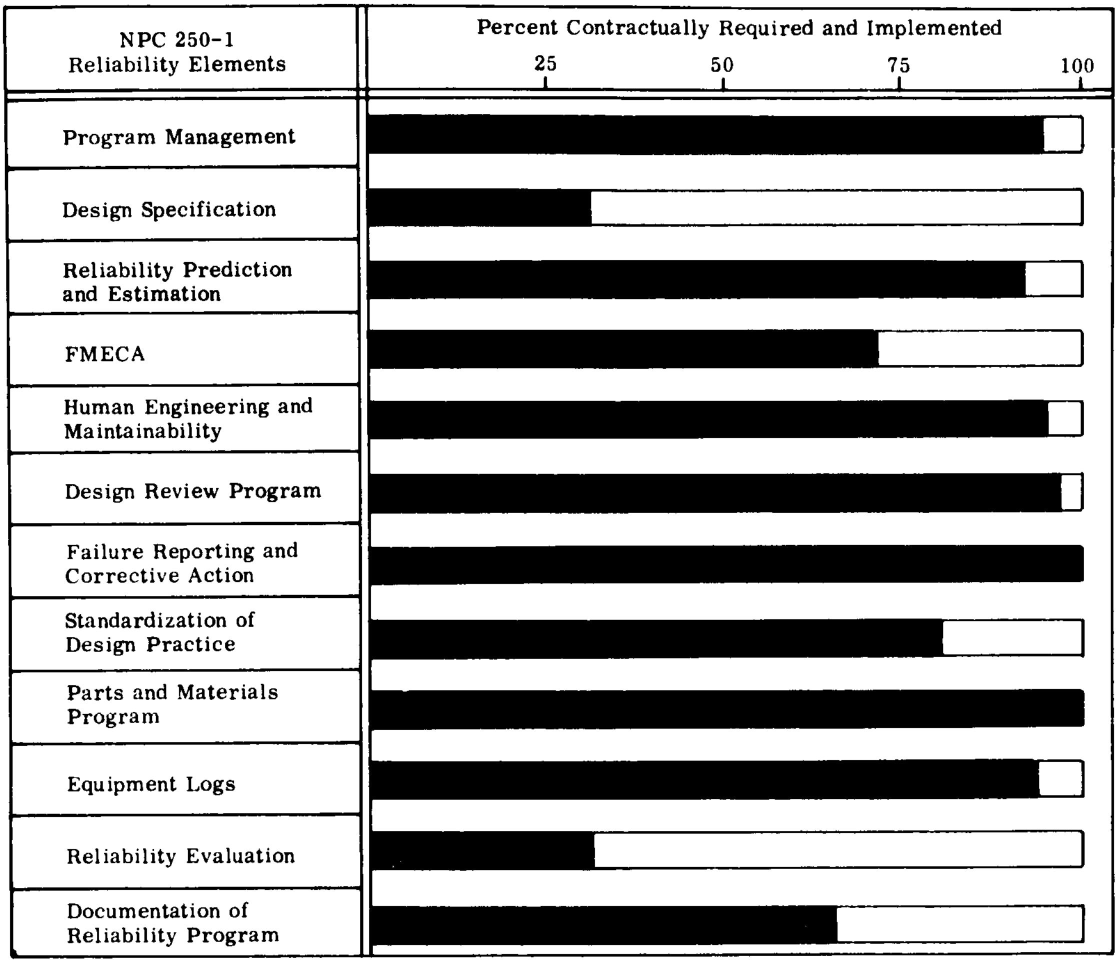


Figure 1-33. Saturn IB/V Instrument Unit Reliability Assurance Evaluation Based on NPC 250-1



Contractor Bendix

Contractor No. NAS8-5399,-13005

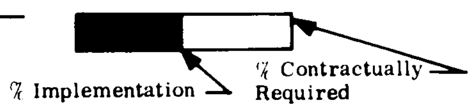


Figure 1-34. Saturn IB/V Instrument Unit Reliability Assurance Evaluation Based on NPC 250-1

Item	Subsystem	Criticality Ranking by Flight Stage			
		S-IU-201			
ST-124M Platform	Guidance	1			
Battery D-10	Electrical	2			
Mod I Switch Selector	Guidance	3			
Battery D-40	Electrical	4			
Pressure Regulator	Guidance	5			
LVDC	Guidance	6			
Flight Control Computer	Control	7			
Platform Electronics Assembly	Guidance	8			
LVDA	Guidance	9			
Gas Bearing Heat Exchanger	Guidance	10			

Items Dropped from Preceding List:

Rank	Item

Figure 1-35. Saturn IB Instrument Unit Ten Most Critical Items

1.4.2.4 Mathematical Modeling

The Saturn IB/V Instrument Unit mission success goal of 0.992 for 6.8 hours was made a part of the NAS8-14000 contract by contract change in April 1965. This goal has been allocated down through the component level based on the Apollo-Saturn V "standard mission." Therefore, since the AS-201 mission varies significantly both in mission profile and subsystem criticalities, the contractor (IBM) predictions for early 200-series missions may exceed the goals.

1.4.2.5 Goals and Prediction

The S-IU-201 stage prediction is 0.992933 for mission success. This prediction is based solely on generic failure rate data as assessment data is insufficient to modify the generic failure data. Figure 1-36 shows the stage reliability prediction trend against the goal of 0.992.

Based on the stage goal of 0.992, the following subsystem goals for S-IU-201 have been established by IBM:

Guidance Subsystem	0.995385
Control Subsystem	0.999627
Electrical Subsystem	0.996988

All other subsystems were not considered flight critical for AS-201 by IBM.

1.4.3 TEST PROGRAM

1.4.3.1 Ground Support Test

Of the 140 reported failures on S-IU-201 through the end of October, 86 remain unresolved, Figure 1-37. Thirteen of these failures are Category II, with seven of these failures remaining unresolved. No S-IU-201 failures are considered Category I since AS-201 is unmanned. Two of the more important failures were:

- The gas-bearing system of the IU assembly which experienced leakage resulting in the inability to determine vehicle attitude. Investigation is in progress.
- Regulator leakage resulting in the same vehicle attitude problem. Investigation is also in progress.

S-IU-200S/500S-II was delivered to the Propulsion and Vehicle Engineering Laboratory on 6 October 1965 from North American. Testing was scheduled to begin 15 November 1965.

S-IU-202 is expected to enter checkout 20 December 1965, and to complete checkout 25 February 1966, at IBM Huntsville.

The acceptance test of the LVDC (production set No. 3) at IBM Owego revealed required circuit changes in the memory module to reduce the noise level. Rework of the S-IU-201 LVDC was agreed to so it was returned to IBM Owego from KSC on 17 November, and is scheduled to be returned to KSC 23 November 1965. No impact on launch vehicle checkout is anticipated.

1.4.3.2 Qualification Test

As of 31 October 1965, component qualification for S-IU-201 was 20 percent behind schedule (see Figure 1-38).

Of the ten most critical S-IU-201 flight-critical items, the following four remain to be qualified:

- Control Computer, 50M32550-1
- LVDC, 50M35010
- LVDA, 50M35011
- Pressure Regulator, 20M42012

Other S-IU-201 flight-critical items that remain to be qualified are:

- Panel Assembly, Gas Bearing Assembly, 20M42023-1
- Meth/Water Accumulator, 20M42040A
- Flex Hose Assembly, 20M42133-1
- LVDC and LVDA Mounting Brackets, 10M22472-1, 10M22473-1
- Pressure Regulators, First Stage, 20M42013-1

- Plug Type V-Box, 40233012
- Control Accelerometers, 50M35022, 50M35032
- 56-Volt Power Supply, 40220807

1.4.4 QUALITY ASSURANCE

The checkout program tapes for S-IU-201 have been coded and checked out. The programs were successfully run during the S-IU-201 checkout.

Status of the Saturn IB/V Instrument Unit quality program in relation to NPC 200-2 is presented in Section 2.

1.5 COMMAND SERVICE MODULE

1.5.1 GENERAL

Milestones that were met during the reporting period include:

a. A level II review of the NASA/MSC Spacecraft Reliability Model for spacecraft 012 was held at MSC from 30 November 1965 through 2 December 1965.
b. Phase I of the Block II Critical Design Review was held at MSC from 16 November through 19 November 1965.
c. The Customer Acceptance Readiness Review for spacecraft 009 was held at NAA/S&ID, Downey, on 20 October 1965.

The schedule of reliability and quality milestones for spacecrafts 009, 011, and 012 is presented in Figure 1-39.

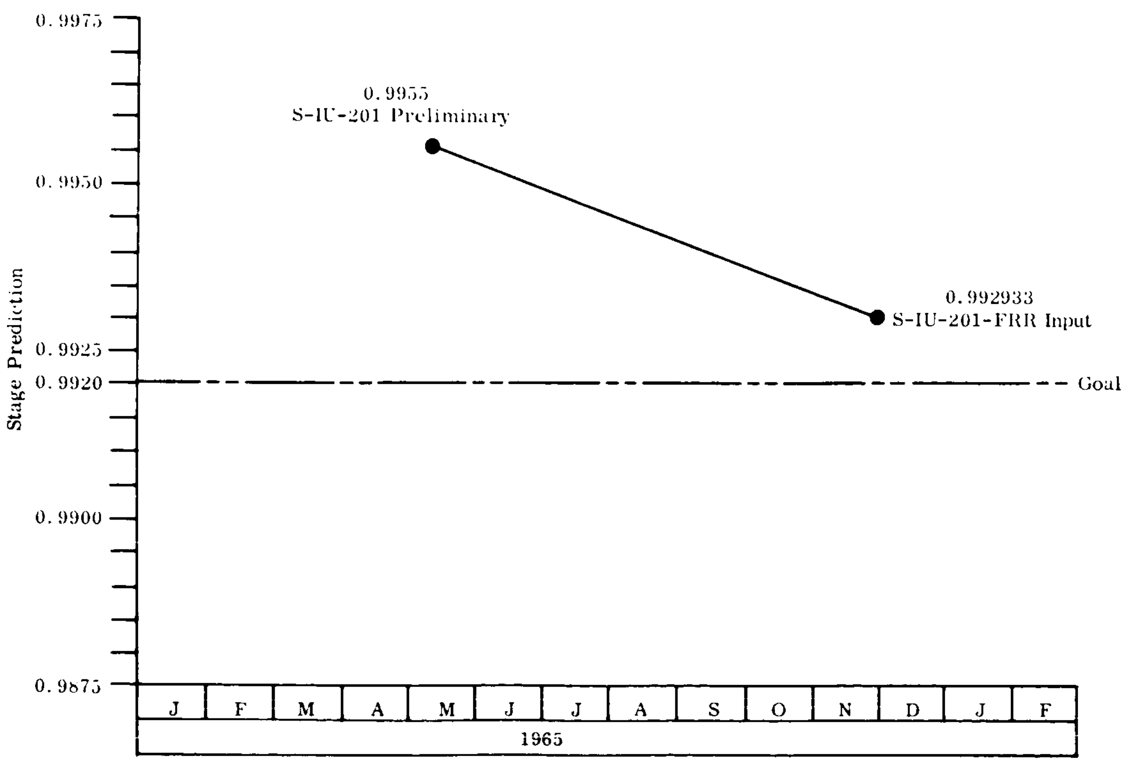


Figure 1-36. Saturn IB Instrument Unit Reliability Trend (Mission Success)

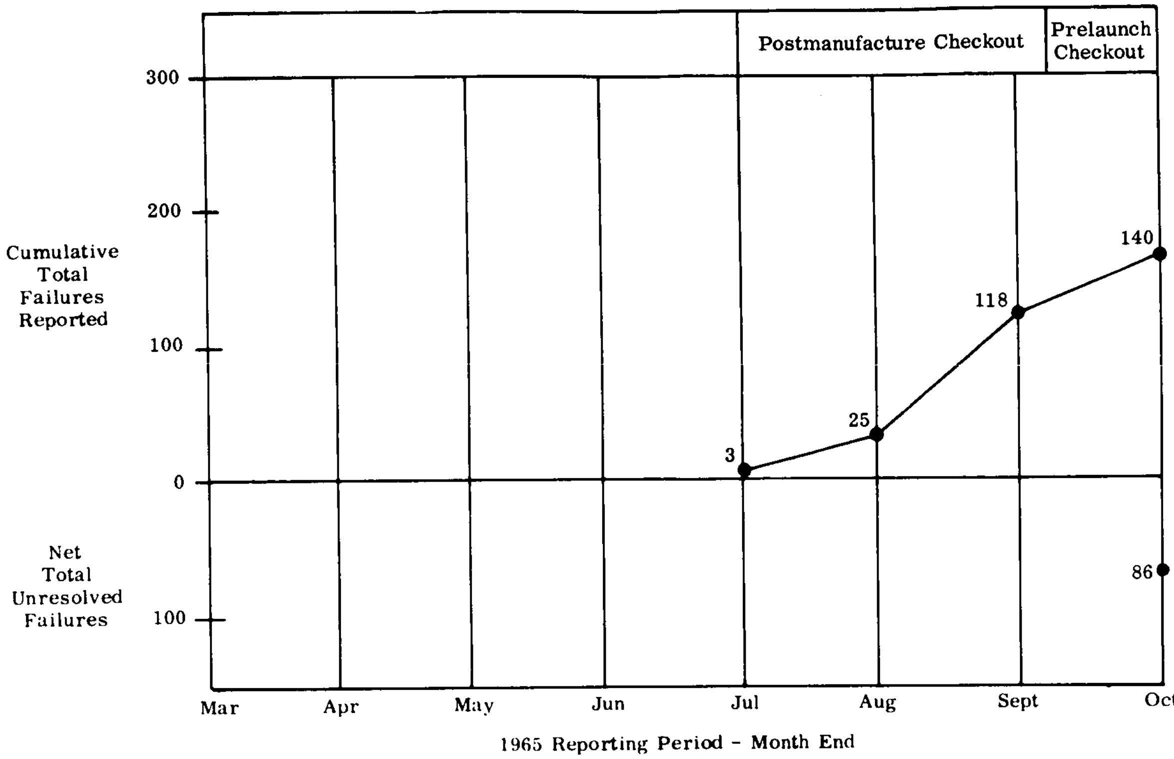


Figure 1-37. S-IU-201 Stage Total Failure Summary and Trend

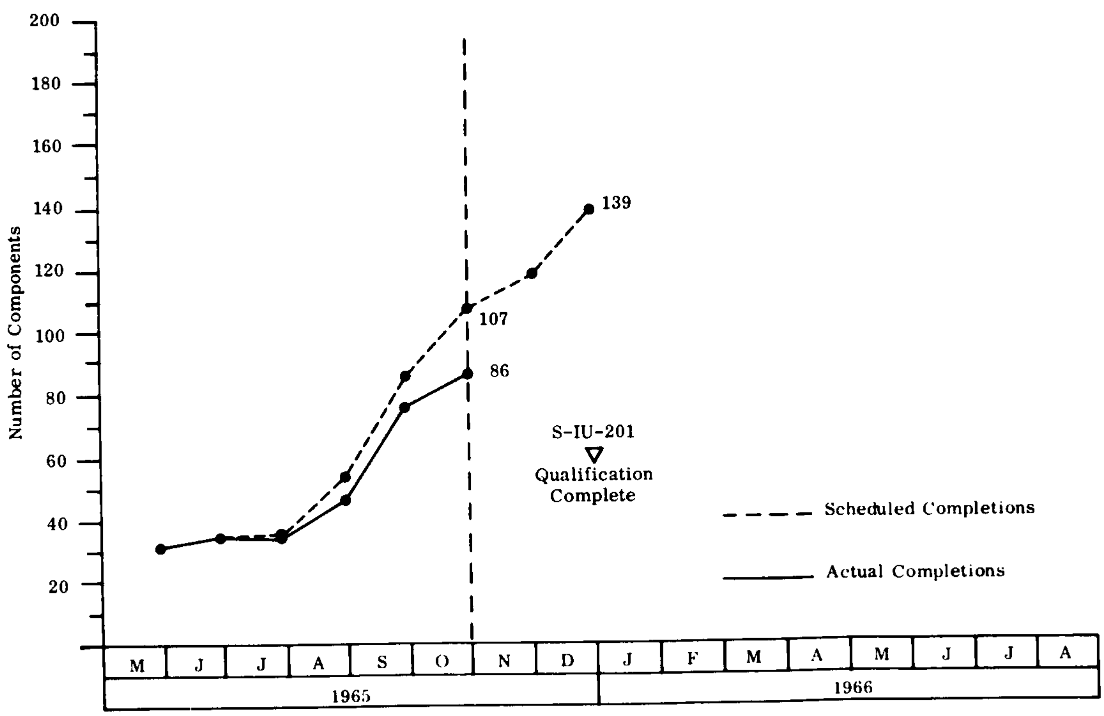


Figure 1-38. S-IU-201 Stage Total Component Qualification

R&QA Program Milestones	1964	1965				1966				1967			
	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Reliability Program Plan - Update				▼									
Quarterly Reliability Status Report		▼	▼	▼	▼	Issued Quarterly							
Monthly Progress Report		▼▼▼	Issued Monthly										
Subsystem FMEA, Logic, SPFS - Preliminary		011 ▼	012 ▼										
Vehicle Logic, Predictions				012 ▼									
Subsystem, FMEA, Logic, SPFS - Approved			011 ▼	012 ▼									
Vehicle Preliminary, Assessment, Prediction - Update					012 ▼								
CDR (DEI)			009 ▼	011 ▼	012 ▽								
FACI (CARR)				009 ▼	011 ▽		012 ▽						
Subsystem FMEA, Logic, SPFS - Final				009 ▽		011 ▽	012 ▽						
Vehicle Assessment and Prediction - Final				009 ▽		011 ▽	012 ▽						
Flight Readiness Report					009 ▽		011 ▽	012 ▽					
Saturn IB CSM Deliveries					009 ●								

KEY -
Scheduled: Software ▽ Hardware ○
Completed: Software ▼ Hardware ●

Figure 1-39. Saturn IB Command Service Module Reliability Assurance Milestones

1.5.2 RELIABILITY ENGINEERING

1.5.2.1 Design

As a result of action items assigned at recent design reviews, the following activities were conducted by NAA Apollo reliability:

a. A study has been initiated to prepare a failure mode and probability analysis for mission success on the main parachute disconnect.
b. A study conducted by the electromagnetic interference group indicates no problem as a result of repeated transient voltage impacts on the pyrotechnic initiators in the Command Module Reaction Control subsystem.
c. An analysis has been started to determine the functional capability of latching and actuating mechanisms. The completion of this study is dependent upon the results of a detailed thermal analysis.

1.5.2.2 Redundancy and Trade-Off Studies

The development and qualification program for the dual mode explosive bolt for the launch escape tower separation has been cancelled because of the detrimental effects of the linear shaped charge firing. The requirements for redundancy will be met by a frangible nut that is scheduled to be flight tested for the first time on spacecraft 011.

The single mode explosive bolt, using the standard Apollo initiator, is scheduled to be used on spacecraft 009. This bolt has been successfully used on all previous flights.

1.5.2.3 <u>FMEA</u>

The 19-volume FMEA for spacecraft 012, dated 1 September 1965, was submitted to MSC/R&QA by NAA Apollo Reliability. These were assessed, and formal comments were provided to NAA at the 28 October 1965 Reliability Review at NAA/S&ID, Downey. Some of the comments were:

a. "Many of the Criticality I single-point failures known to exist on Block I equipment did not appear on the summary sheet or in the FMEA."
b. "A frequent criticism from this review was that the analyses were not performed in enough detail for subsystem reliability engineering use as a working, reference tool."
c. "Of the 19 volumes reviewed, only six were considered acceptable analyses."

It is the intent that the FMEA's are to be a major consideration in:

- Design reviews
- Trade-off studies
- Mission analysis
- Test planning
- Checkout procedures

Since this FMEA will be used as the basis for all the Block I spacecraft FMEA's, it is necessary that this analyses meet the reliability objectives.

The five most critical itmes on spacecraft 009, based on the contractor FMEA, is presented in Figure 1-40. A description of the function of the critical items noted on Figure 1-40 is presented below. Also indicated is the corrective action that has been taken.

- <u>Attitude Gyro (SCS)</u>
  Function - The attitude gyro senses pitch, yaw, and roll attitude changes and provides attitude-error signals for display and automatic attitude control through the stabilization and control subsystem. (There is no ground-command back-up on this flight.)
  Action - None

- <u>Rate Gyro (SCS)</u>
  Function - The rate gyro provides attitude change rate data for display as well as damping and stabilization signals to the stabilization and control subsystem. (There is no ground-command backup on this flight.)
  Action - None

- <u>Helium Squib Valve (RCS)</u>
  Function - The squib-operated valve actuates a helium purge of the reaction control subsystem fuel before entry into the atmosphere. This is necessary to reduce the possibility of an explosion.
  Action - None

- <u>DC Power Control Box (EPS)</u>
  Function - The four power diodes in the dc power control box isolate the batteries from each other and the dc bus.
  Action - None. A potential problem exists should a terminal screw short to the inside wall of a hole drilled through the heat sink. The bolt is insulated by an anodized aluminum plate which must withstand several mechanical, environmental, and chemical exposures, plus handling. Since these diodes are not accessible and since they passed a 150-volt dc hi-pot test, the decision was made to make no modifications on this flight.

- <u>Data Storage Recorder (COMM)</u>
  Function - The data storage recorder is required to record the heat shield temperature in addition to other physical data. Since one of the primary objectives of spacecraft 009 is to verify CM heat shield performance, this recorder performs a vital function.
  Action -
  a. A new tape will be installed prior to launch.
  b. One speed only will be used during spacecraft 009 operation, and no reversals will be required.
  c. Heat shield temperature will be paralleled onto the flight qualification recorder.

1.5.2.4 <u>Mathematical Model</u>

The "Preliminary Apollo Reliability Modeling Document" which was presented by NAA to NASA in May 1965, is now being revised to improve the initial mathematical model. The revised Apollo Reliability Mission Model will be capable of accepting Boolean expression units of system logic to permit calculation of mission success and crew safety reliability. In addition, a routine will be added to provide cathode ray tube logic diagrams as printouts from the Boolean expressions. The final issue of this document is scheduled for release by December 1965.

1.5.2.5 <u>Apportionment and Prediction</u>

Apportionments for the Block I spacecraft were scheduled to be completed by the contractor by December 1965. However, at the 28 October 1965 review meeting at Downey, it was decided that there was no necessity for Block I apportionments since the apportionments for the Block II spacecraft would suffice.

A schedule of apportionments, predictions, and assessments (as of 28 October 1965) is presented below:

Item	Completion Date Scheduled	Completion Date Estimated
Logic Diagrams & Failure Rates	Oct 8, 1965	Oct 22, 1965 (to be rescheduled)
Upgrade Current Mission Analysis Computer Program	Aug 6, 1965	Dec 3, 1965
Spacecraft 009 Success Index	Nov 15, 1965	Dec 15, 1965
Spacecraft 012 Success Index	Oct 29, 1965	Jan 7, 1966
Spacecraft 012 Predictions	Oct 29, 1965	Dec 15, 1965
Spacecraft 012 Reliability Data Review	Nov 5, 1965	Nov 5, 1965 (to be rescheduled)
Block I Predictions	Nov 22, 1965	Dec 11, 1965
Block II Apportionments & Predictions	Jan 1, 1966	Jan 31, 1966
Block II Data Review	Dec 3, 1965	Dec 10, 1965
Block II Reliability Prediction Results	Jan 10, 1966	Feb 10, 1966

Item	Subsystem	Criticality Ranking by Flight Stage			
		SC-009			
Attitude Gyro-Pitch and Yaw	Stabilization and Control	*			
Rate Gyro-Pitch and Yaw	Stabilization and Control	*			
Helium Squib Valve	Reaction Control	*			
DC Power Control Box	Electrical Power	*			
Data Storage Recorder	Instrumentation	*			

*Items not ranked

Items Dropped from Preceding List:

Rank	Item

Figure 1-40. Command Service Module Five Most Critical Items

1.5.3 TEST PROGRAM

1.5.3.1 Ground Support Tests

The supporting ground test program for spacecraft 009 and spacecraft 011 is presented in Figure 1-4. This chart indicates that all the tests in support of spacecraft 009 are complete, with the exception of the flight of spacecraft 002 (LJ II-5).

Spacecraft 002, which was originally scheduled to be flown on 15 October 1965, has been rescheduled for 15 December 1965. (The launch planned for 8 December 1965, was postponed because of a malfunction in the LJ II autopilot.) This test is significant because it will be the first spacecraft-configured CSM to be flight tested. It is expected to reveal data on the structural integrity of the spacecraft. The first-order test objectives for this flight are:

a. To demonstrate satisfactory launch escape vehicle performance for an abort in the power-on-tumbling region.
b. To demonstrate the structural integrity of the launch escape vehicle airframe structure.

1.5.3.2 Certification Tests

The certification tests for spacecraft 009 were completed on 30 November 1965. The latest schedule indicates 291 tests planned and completed. This represents a deletion of 57 tests as a result of a re-evaluation of the requirements for spacecraft 009.

Problems reported in the previous R&QA status report and the corrective actions are as follows:

- Reaction Control Subsystem
  Problem - The CM and SM nitrogen tetroxide propellant tanks have failed when tested with nitrogen tetroxide oxidizer at elevated temperature and maximum working pressure.
  Corrective Action - Possible solutions which are being evaluated are:
  a. Teflon coat the inside surface of the tanks.
  b. Shot-peen the inside surface of the tanks.
  c. Use an inhibitor.

- Ordnance Devices
  Problem - Various cartridges have failed certification tests due to pressure rise times which did not meet specification requirements.
  Corrective Action - The specification has been changed. Interface tests with the new units are now being conducted.

- Service Propulsion
  Problem - The gimbal actuator clutches are demonstrating greatly reduced service life.
  Corrective Action - The problem may be resolved by relaxing the gimbal rate requirements to prevent overheating.

Figure 1-41 identifies the failure summary and trend during the acceptance test program for spacecraft 009. Some examples of the 42 critical failures are:

a. The umbilical cutter (guillotine) ordnance has proved to be too forceful for its housing causing shrapnel. Also, the cutter blade during travel has forced the umbilical bundle to break away from the command module. North American is strengthening the ordnance housing, adding a debris trap, and is attempting to improve the bonding on the umbilical bundle.

b. The tension tie cutter showed too low an ordnance charge resulting in the inability to sever. For spacecraft 009, the charge will be repacked, but design improvement is needed in this area.

c. The cartridges which cause separation of the LES/CM heat shield apex cover have too high breech pressure. Although they overstress the system, no failures have been recorded against spacecraft 009.

d. The dual-drive disconnect blows out the initiator properly, but fails to retain its momentum and ends up hanging from the wire harness.

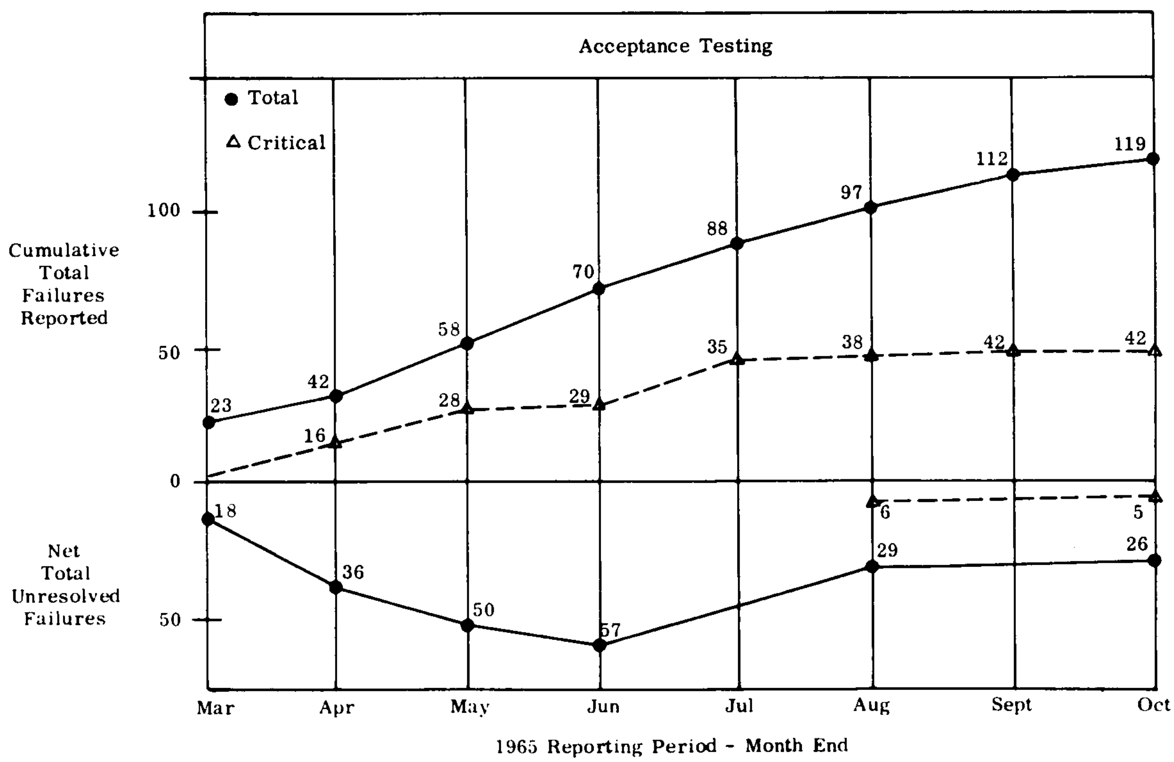


Figure 1-41. Spacecraft 009 Total Failure Summary and Trend

Figure 1-42 shows the failure summary and trend for spacecraft 011.

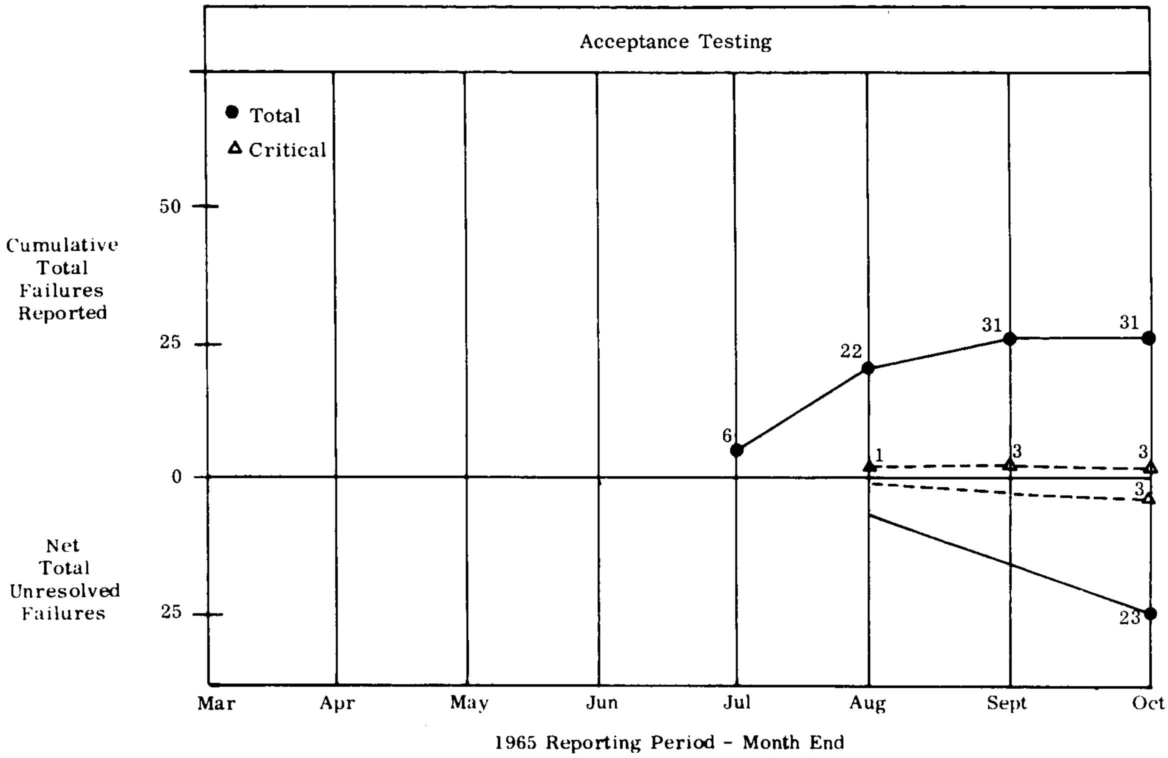


Figure 1-42. Spacecraft 011 Total Failure Summary and Trend

1.5.4 QUALITY ASSURANCE

1.5.4.1 Quality Trends

Figures 1-43 and 1-44 summarize the NAA failure report status through September 1965.

Figure 1-45 shows the trend in material review actions per 1000 manufacturing hours at NAA.

Figure 1-46 shows the trend in defects per 1000 manufacturing hours at ACED for the G&N system.

Figure 1-47 shows the trend in waivers granted per month on the G&N system.

Figure 1-48 indicates the failures as of 8 December 1965 on each G&N system.

Figure 1-49 shows age distribution of unsolved G&N failures as of 30 November 1965.

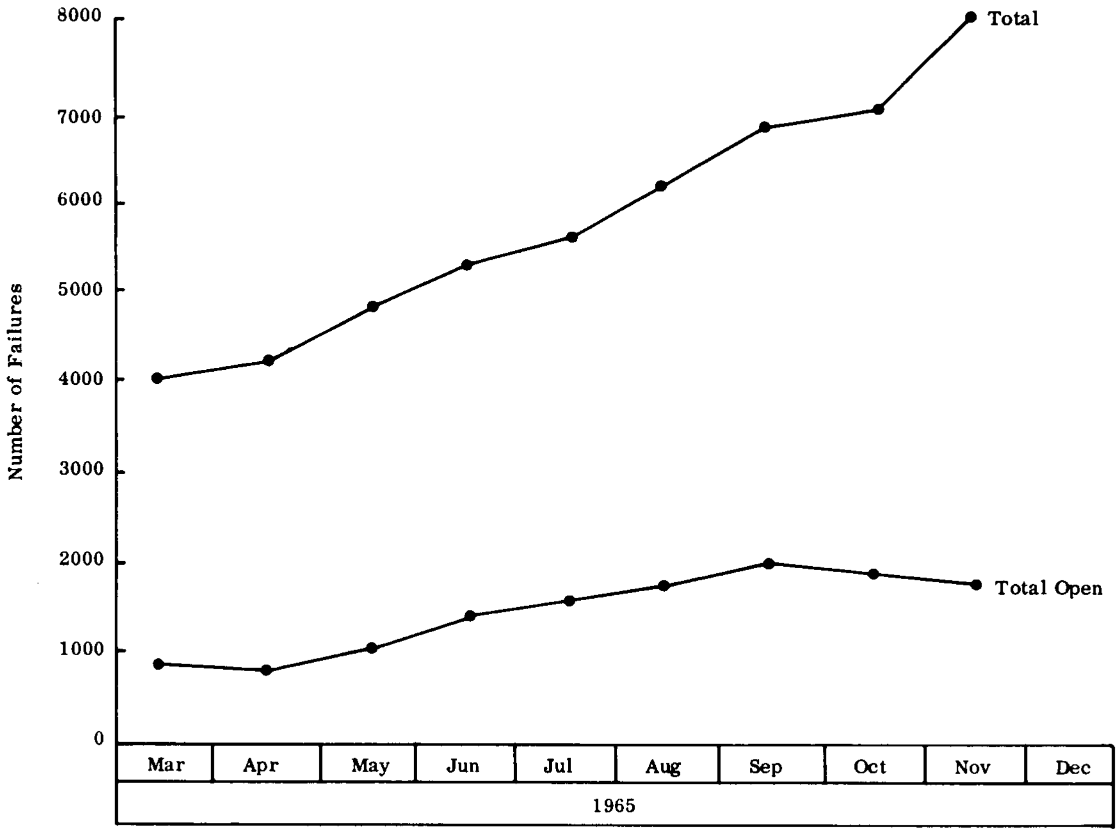


Figure 1-43. Summary of NAA Failure Reports Cumulative (Spacecraft and GSE)

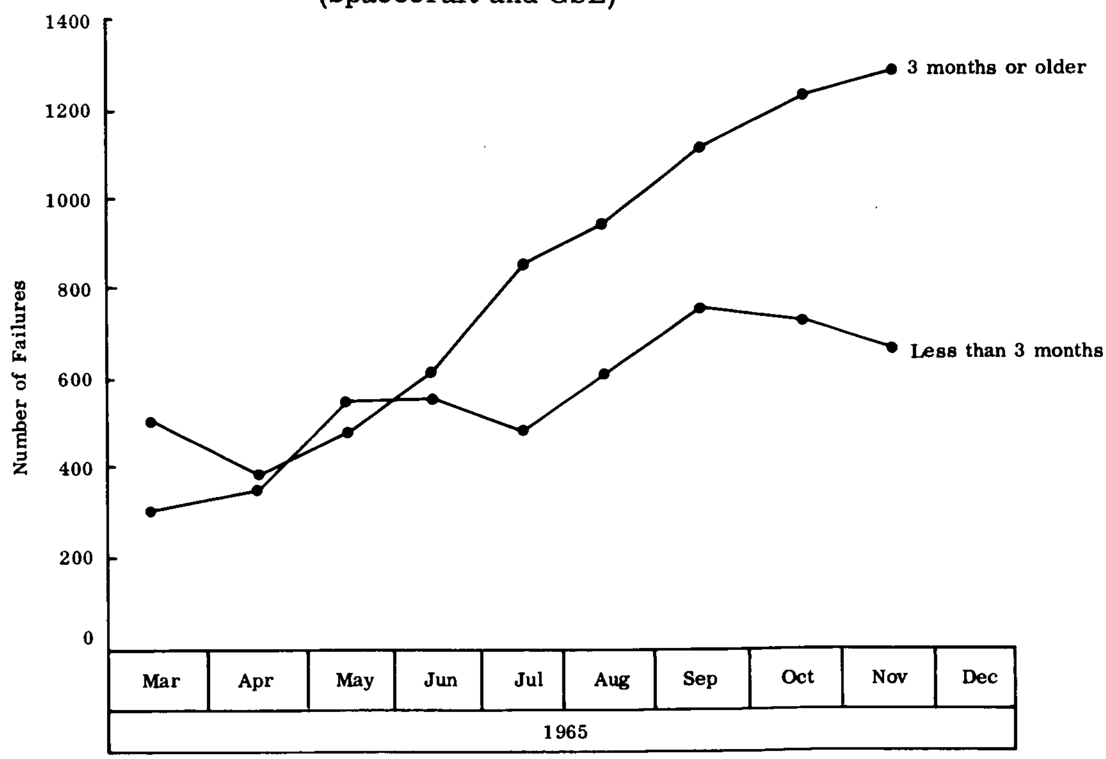


Figure 1-44. Summary of NAA Failure Reports Corrective Action Incomplete

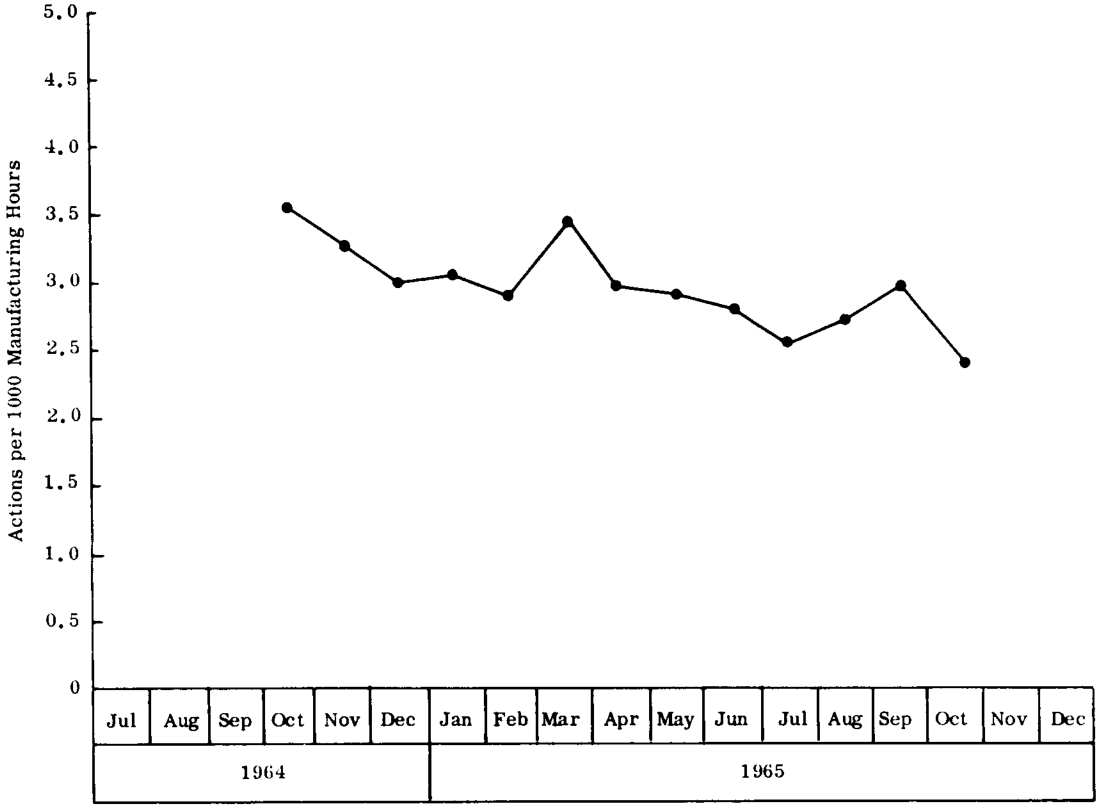


Figure 1-45. NAA CSM Material Review Actions per 1000 Manufacturing Hours

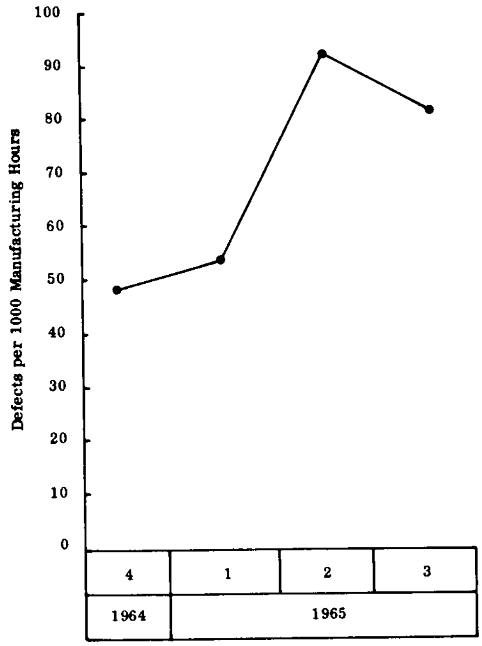


Figure 1-46. ACED Defects per 1000 Manufacturing Hours Apollo G&N System

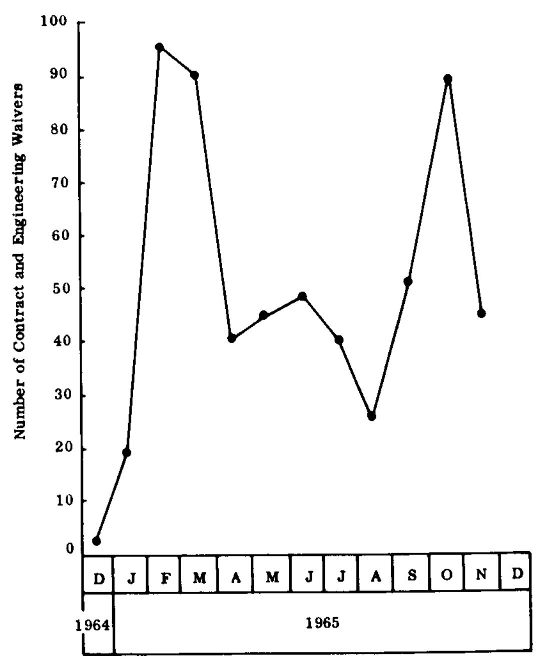


Figure 1-47. Contract and Engineering Waivers Granted per Month on Apollo G&N System

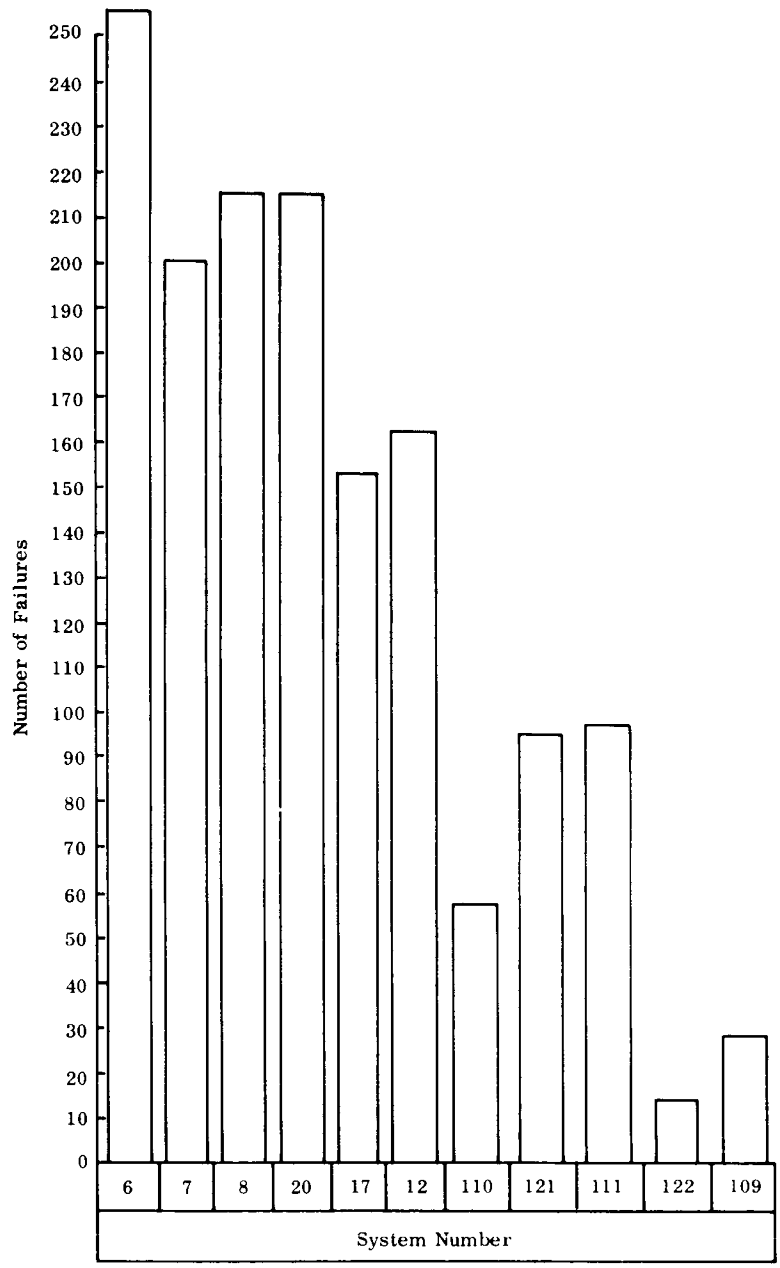


Figure 1-48. ACED G&N Failures by System as of 8 December 1965

[redacted]

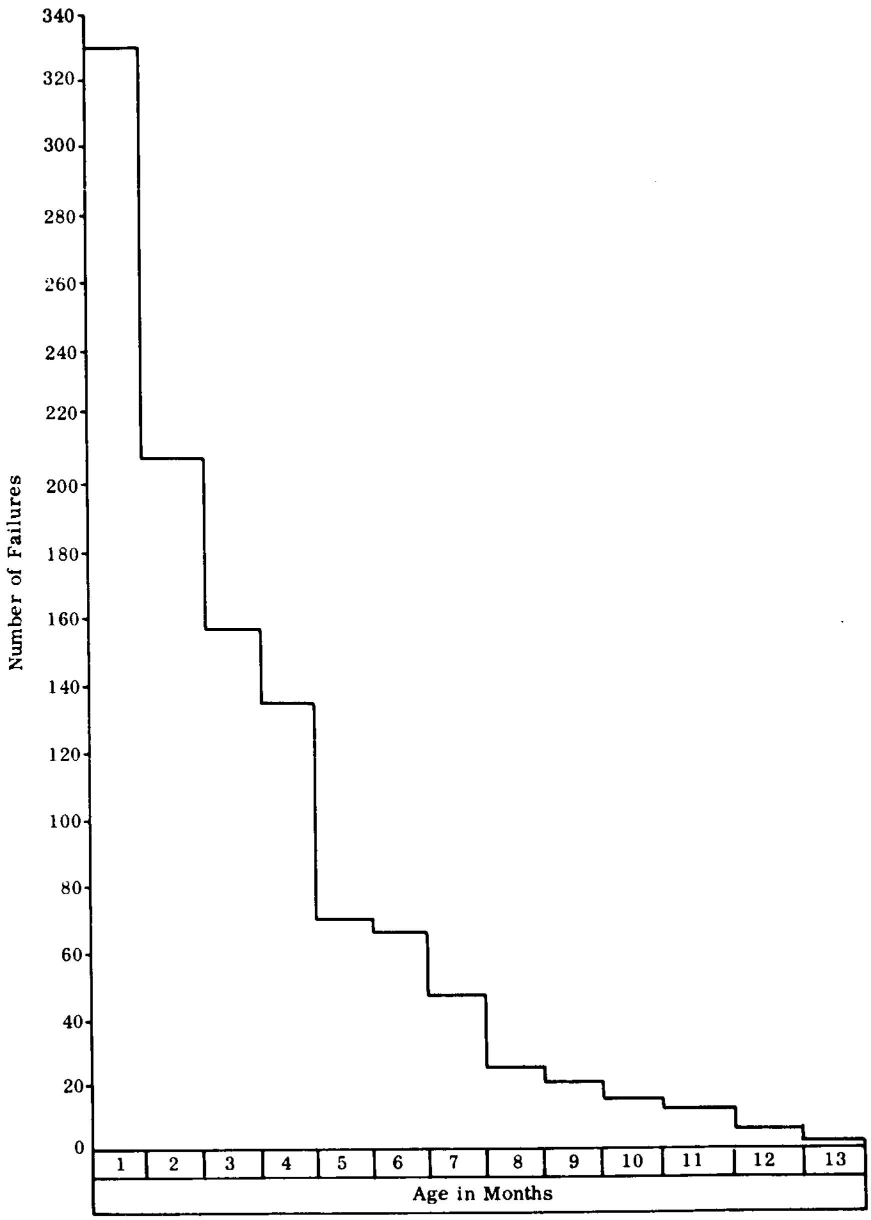


Figure 1-49. Distribution of Unresolved G&N Failures as of 30 November 1965

[redacted]

1.5.4.2 Quality Problems

The CSM 009 Customer Acceptance Readiness Review (CARR) was held at NAA, S&ID, Downey, on 20 October 1965. The NAA CARR Board accepted the spacecraft for shipment to KSC.

The CARR report lists 247 "Major Abnormal Conditions" (major, controversial, constraining, or unresolved problems) which were considered as part of the spacecraft 009 history during the review. These major abnormal conditions are described as "equipment replacements", "discrepancies" or "other anomalies" by the report. The instrumentation system had the highest number of abnormal conditions assigned (45), followed by the propulsion systems (42), and electrical power system (30). The distribution of types of failures which occurred is illustrated in Figure 1-50.

The CARR report indicated a total of 37 waivers have been permitted on CSM 009 principally in the EPS, ECS, and Service Propulsion Systems.

Total unqualified parts for CSM 009 at CARR was 135. Distribution of unqualified parts by system is shown in Figure 1-51.

Unsatisfied NASA Quality Assurance conditions noted in the CARR report are as follows:

- Electrical Power System:
  - a. Foam rubber filler used in aft compartment raceways is both flammable and moisture absorbent.
  - b. Wire splices are not waterproof.
  - c. Electrical connectors come apart. A temporary fix using safety wire to hold the connectors together has been put into effect.

- Environmental Control System:
  - a. Moisture inside command module from condensation on coolant lines.
  - b. Reverification test of the cabin pressure relief valve not performed after reinstallation in command module.
  - c. Cleanliness inside command module not satisfactory. Shield wire clipping and other debris found in and around wire bundles and under components in spacecraft.

- Instrumentation System:
  - a. Giannini propellant utilization system has had no checkout performed.
  - b. Electrical bonding for noise reduction not accomplished on all components.

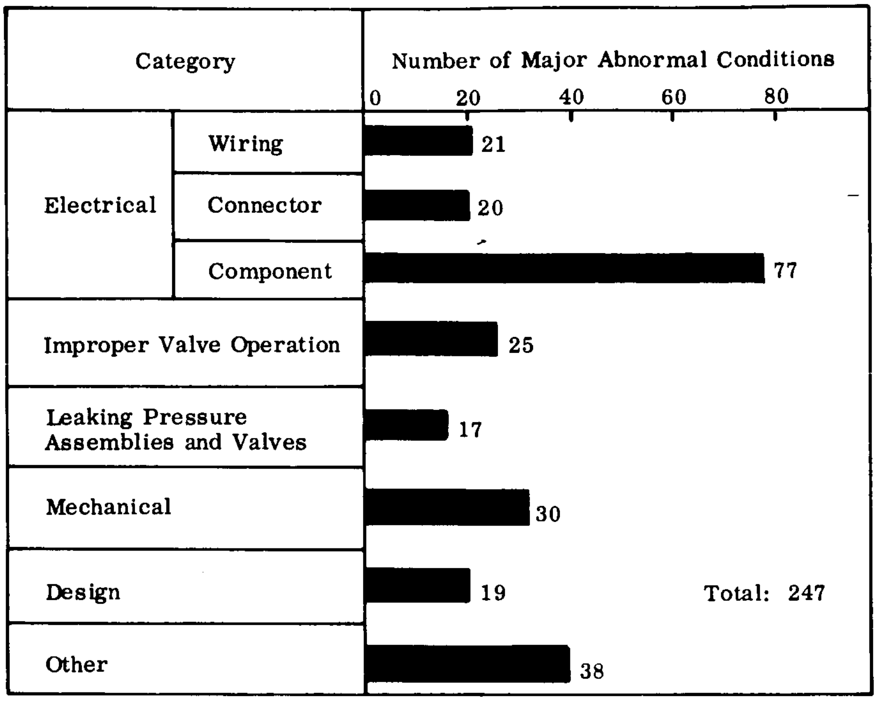


Figure 1-50. Types of Major Abnormal Conditions CARR Report, CSM 009

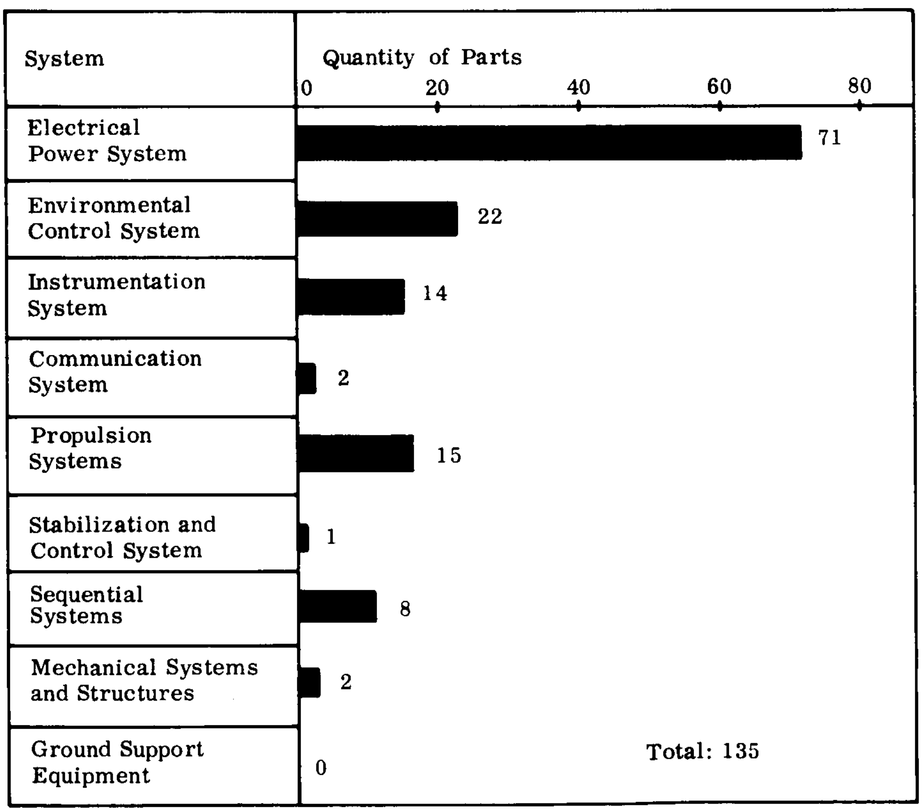


Figure 1-51. Unqualified Parts Within Each System CARR Report, CSM 009

- Ground Support Equipment:
  a. The ACE cathrode ray tube is being driven to upper and lower limits of the downlink equipment between the ACE carry-on and interleaver.
  b. NAA OCP emergency shut down procedure does not include General Electric equipment.
  c. The out-of-tolerance indication on the alphanumerical display unit, ACE control room, has not been resolved satisfactorily.

Corrective action for problem areas cited in the CARR report is being accomplished by assignment of action items in the minutes of the report itself and by AFRM 009 failure review meetings, the first two of which were conducted at KSC on 4 November and 8 November, respectively.

Approximately 306 structural nonconformances have been reported on spacecraft 012. This large number raises the question of the true structural integrity of the spacecraft which is the first to be used in manned flight.

1.5.4.3 Quality Program

Figure 1-52 shows the status of the spacecraft quality program in terms of scheduled and completed milestones. These milestones pertain to activities associated with the prime contractor.

Operation of the MSC Failure Data Center is continuing. Information is being received from NAA and ACED. Status at the end of this quarter is as follows:

- NAA critical failures (24-hour reports), 623 reports to date, 331 are still open pending receipt of data.

  Total NAA Failures - 7749, with 1623 still open. Spacecraft subsystems with the highest failure records are SCS, telecommunications, EPS, SPS, RCS, and instrumentation. Failures in GSE comprise about half the total open failures.

- ACED critical failures (24-hour reports), 84 reports received, 57 are still open pending receipt of data.

  Total failure tape reporting system from ACED is not yet operational.

- GAEC critical failure system is not yet in operation, because the qualification program does not begin until 1966.

  Total failure tape reporting system from GAEC has been initiated, but submittal of tape report is irregular and not per schedule.

1.6 LAUNCH COMPLEX AND GSE

1.6.1 GENERAL

To accommodate the launch and test schedules, a fifth ACE-S/C station at MILA will be necessary. The exact location for this station has not yet been determined. A plan of action to utilize the Government Furnished Equipment now in use at the Systems Test Facility, Daytona Beach, has been published.

Documents	1965 J	A	S	O	N	D	1966 J	F	M	A	M	J
Quality Program Plans												
NAA		▽^{1}										▽^{1}
ACED						▽						
GAEC								▽^{1}				
GE/DB ACE			▽^{1}									
GA/NAA	Previously submitted											
GA/ACED				▼								
GA/GAEC				▽^{1}								
Quality Status Reports												
NAA	▼	▼	▼^{2}				▽			▽		
GAEC	▼	▼^{2}				▽			▽			
ACED			▼^{2}			▽			▽			▽
GE/DB ACE	▼	▼	▼^{2}	▽	▽	▽	▽	▽	▽	▽	▽	▽
GA/NAA (Monthly)	▼	▼	▼^{2}	▽	▽	▽	▽	▽	▽	▽	▽	▽
GA/GAEC (Monthly)	▼	▼	▼	▼^{2}	▽	▽	▽	▽	▽	▽	▽	▽
GA/ACED (Monthly)	▼	▼	▼	▼^{2}	▽	▽	▽	▽	▽	▽	▽	▽
GA/GE/DB ACE	▼	▼	▼^{2}	▽	▽	▽	▽	▽	▽	▽	▽	▽
Quality Program Reviews												
NAA (Monthly)			▼	▼	▼	▽	▽	▽	▽	▽	▽	▽
ACED (Monthly)	▼	▼	▼	▼	▼	▽	▽	▽	▽	▽	▽	▽
GAEC (Monthly)			▼	▼	▼*	▼	▽	▽	▽	▽	▽	▽

▽ - Scheduled

▼ - Actual

▽^{1} - Update

▼^{2} - Latest Report Received

*November and December Reviews were held at the same time in December, i.e., Data from both months discussed at the December meeting.

Figure 1-52. Spacecraft Quality Program Milestones

ACE-S/C stations 1 and 2 were used for facility verification, program debugging, and spacecraft 009 testing. Station 1 was configured to support hypergolic (RCS) testing and the spacecraft Service Propulsion System testing on Pad 16. Station 2 was configured to support spacecraft testing in the Manned Space Operations Building (MSOB) and LC-34B.

First Article Configuration Inspections (FACI's) are being performed on LC-34 launch facilities and will be performed on LC-37B launch facilities as the GSE systems are completed. The first FACI to be performed on LC-34 identified the following problems:

a. No End Item Specification was available.
b. The hardware, as built, did not agree with the drawing configuration in several areas.
c. Test procedures were satisfactory, but needed to be put under more formal change control.
d. There was no change control feedback system.
e. The DD250 did not show action on disposition of open items.
f. The status of action required on waivers was not available.

Action items were assigned to correct the deficiencies encountered on the first system FACI.

Testing and checkout of spacecraft 009 has progressed satisfactorily with no major problems arising from the test facilities or GSE. All work is progressing on schedule on LC-34 and LC-37B.

1.6.2 LAUNCH COMPLEX RELIABILITY ENGINEERING

1.6.2.1 Launch Complex 34

The FMEA's and criticality analyses for LC-34 have been updated and are in the process of being released. Figure 1-53 depicts those six items with the highest criticality numbers that could cause loss of the vehicle, endanger crew safety, or cause loss of life (Priority I items). The rankings were valid as of 10 September 1965. Later revisions are not presently available.

Figure 1-54 shows the total reports written on Launch Facility GSE Complex 34 from May through October. The reports have not been segregated between failures and other unsatisfactory conditions, and criticality classifications have not been assigned. It is, therefore, not possible to identify the number of failures which would cause a safety hazard or a mission abort. No information is available on the status of resolution of failures for recurrence control.

The apparently significant decrease in reports for October as compared with August and September is actually due in large part to the lag time for reports to reach the data system. The total figure for October is expected to be more on the order of the August and September figure.

The source of this information is the initial KSC R&QA status report in accordance with paragraph 5.3.1 of NHB 5300.1. It is anticipated that future reports will include more meaningful information as KSC gains additional experience.

NOTE

The criticality numbers may be lowered on some of the items, as follows, if the remedial actions are implemented.

- Liquid H_2 System - Implementation of a design change to remove two components.
- Pneumatic System - Removal of relief valves.
- Swing Arms - Installation of a redundant arm rotating system will reduce the number to zero. Study is in progress.

1.6.3 ACE-S/C RELIABILITY ENGINEERING

1.6.3.1 GE/ASD Reliability Engineering

The FMEA for all station ACE-S/C, excluding the Digital Test Command System (DTCS) and the Digital Test Monitoring System (DTMS), which is the responsibility of NAA and GAEC was published by GE/ASD. Final FMEA's on the GFE portion of ACE-S/C will be published during the first quarter of 1966.

Item	Subsystem	Criticality Rank by Launch Complex			
		LC-34			
Swing Arms (4)		1			
Pneumatic Distribution System		2			
Liquid Hydrogen System		3			
Hold Down Arms		4			
Pneumatic Facility		5			
Liquid Oxygen System		6			

Items Dropped from Preceding List:

Rank	Item

Figure 1-53. Saturn IB Launch Complex Six Most Critical Items

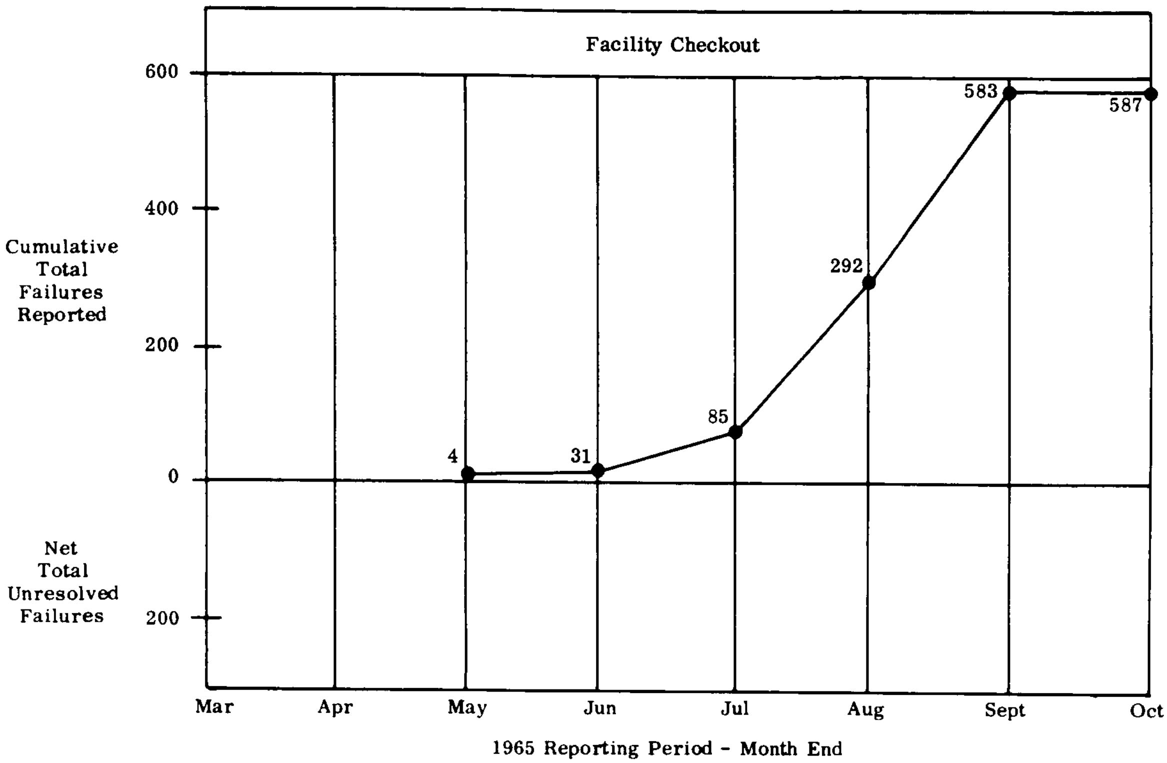


Figure 1-54. Saturn IB GSE - Launch Complex 34 Total Failure Summary and Trend

The failure report form has been revised and renamed to permit the gathering of more significant maintainability information. GE/ASD has been given increased responsibility for failure analyses of Government Furnished Equipment. Plans, forms, and necessary procedures were generated and published to enhance the flow of paper and material between the responsible companies.

An operation readiness program was started with detailed plans and approaches defined. The program will review all test and checkout areas at KSC where ACE-S/C equipment is utilized. The program will also determine the probability that the systems will perform satisfactorily during specified operational time periods.

Significant changes were made to the MILA mission reliability block diagrams. In the uplink model, "J" boxes and the computer console were added. The "J" boxes are in series with the manual data entry C, R, and K starts and with the remaining uplink system. In the downlink model, the computer console was added. This added equipment has had a significant effect on the MTBF's and reliability assessments. The effect on the MTBF's is depicted in the curves in Figure 1-55.

In general, ACE-S/C performance continues to be good as indicated by the Mean Hold Time curve depicted in Figure 1-56.

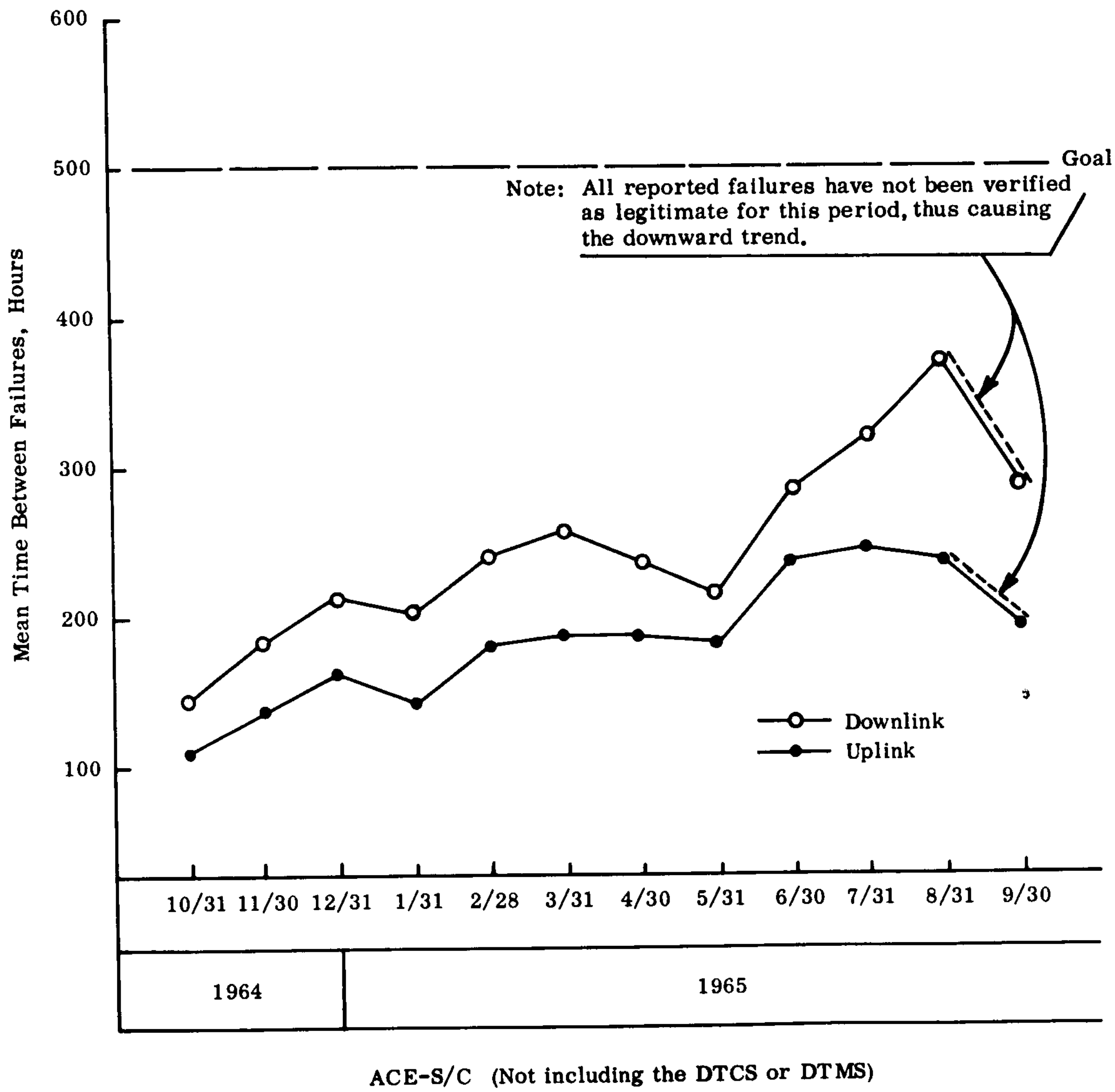


Figure 1-55. MILA Mission Evaluation T-1 to T-0 Trend Chart

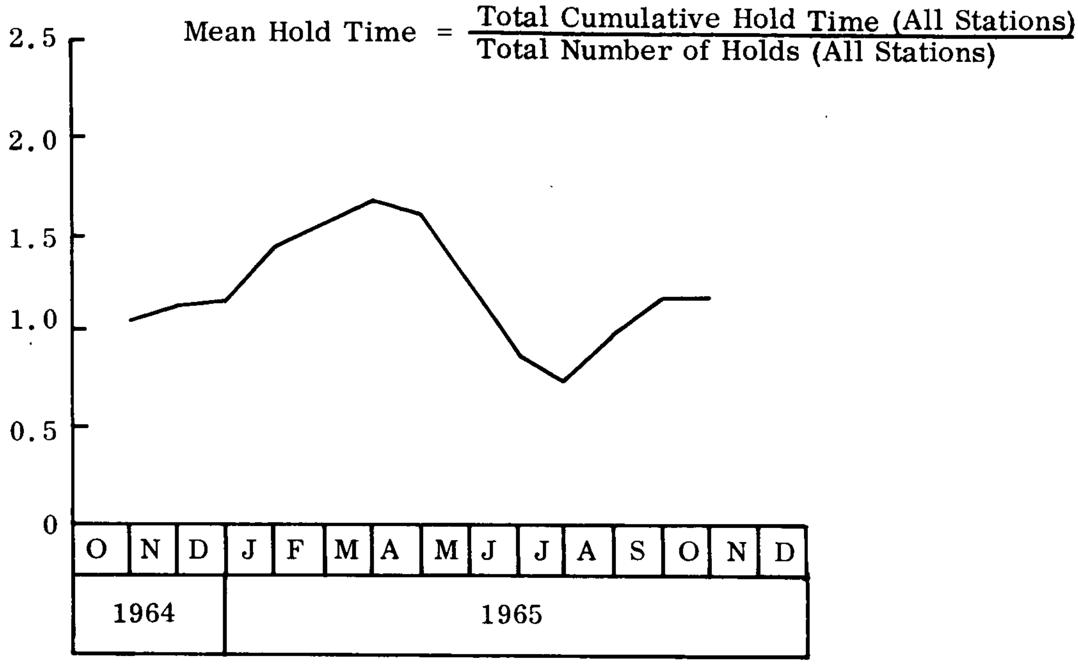


Figure 1-56. ACE-S/C Availability

1.6.3.2 DTCS and DTMS ACE-S/C Reliability

The Digital Test Command System (DTCS) portion of the ACE-S/C uplink system has suffered numerous failures. The predominant component failure has been a microminiaturized 3K-ohm film resistor. The total delivered equipment incorporates about 50,000 of these resistors, and replacement is impractical. The cause of the failures is known; however, the circuit design prevents a complete resolution of the problem. The effects on checkout during critical countdown period, if additional failures occur, are not presently known. Investigations are being made in this area.

Failures in the downlink subcommutators and some signal conditioners were analyzed. The signal conditioners will be sealed to alleviate the problem, and high reliability parts have been substituted in the signal conditioner redesign.

1.6.4 ELECTRICAL SUPPORT EQUIPMENT (ESE) RELIABILITY ENGINEERING

1.6.4.1 Saturn IB ESE

The ESE was assessed to have a reliability of 0.85019 during the last seven hours prior to launch. Maintenance can be performed on some of this equipment, and if completed within two and one half hours during the last seven hours of countdown, the reliability will increase to 0.90729. The assessment is based on generic failure. When actual failure data becomes available, the assessments will be updated.

The over-all reliability goal for ESE is 0.9842 and is apportioned as follows:

General Electric	0.99
RCA	0.99
Bendix	0.99989

There are eleven part-level items in the General Electric portion of ESE that can directly affect the probability of mission success. Nine of these apply to the S-IB Stage ESE and two to the S-IVB Stage ESE. The eleven parts consist of diodes and relays with the diodes having the highest criticality numbers for both stages.

Reliability program status on contracts for General Electric ASD and Sanders Associates ESE are shown in Figure 1-57 and 1-58, respectively. The total progress to date for each area is shown as a solid black bar. A complete re-evaluation is in process on RCA status, and no data is presently available.

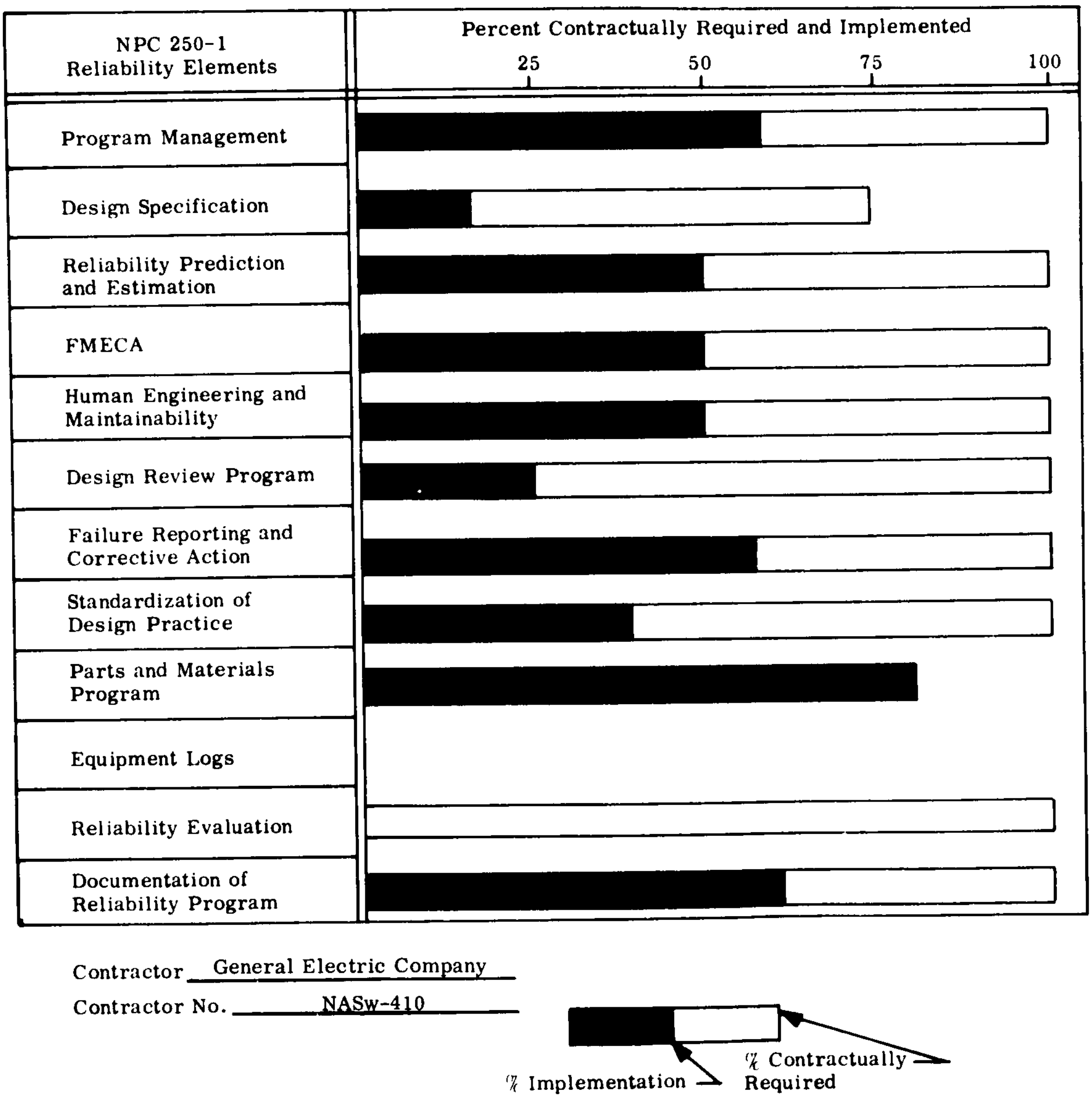


Figure 1-57. Saturn IB ESE Reliability Assurance Evaluation Based on NPC 250-1

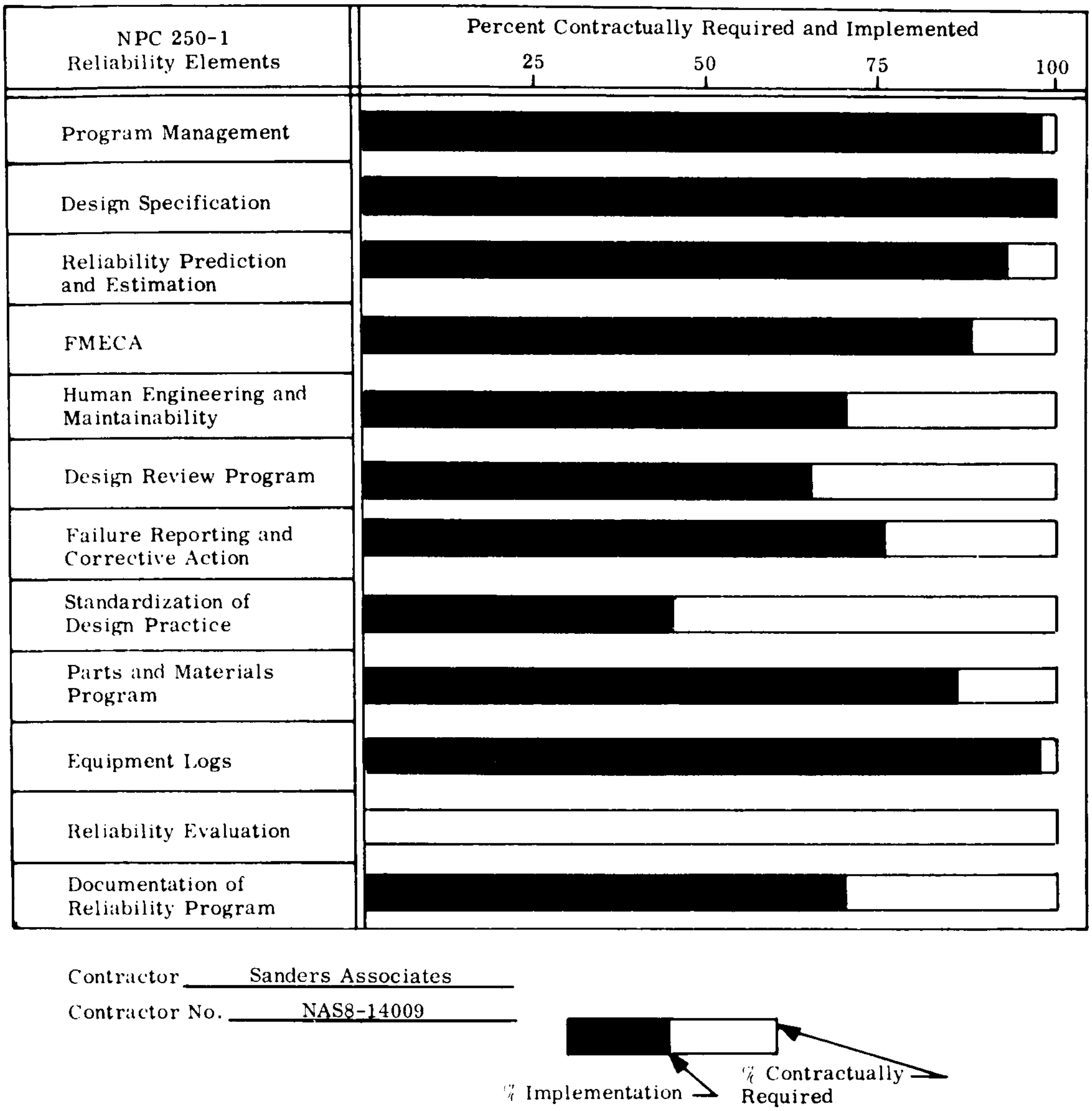


Figure 1-58. Saturn IB ESE Operational Display System Reliability Assurance Evaluation Based on NPC 250-1

1.6.5 TESTING PROGRAM

1.6.5.1 Launch Complex 34

KSC has initiated a qualification test planning effort. An ideal qualification test program for the critical holddown arms will be generated. This program will be compared with the actual testing completed to determine if any additional testing is necessary.

The results of the test planning and evaluation will be used as an aid in defining the work necessary to provide qualification status and test planning for all critical GSE items.

Figure 1-59 shows problems encountered on failures that have occurred on Priority I systems during September and October 1965.

Functional System	Trouble or Failure
Launch Mast	Burned sections in weld and anodized surface scratched on inner sleeve weldment
Umbilical Swing Arm	Wrong connector, no steel sheath and not dynathermed, on cable assembly
Range Instrumentation	LH_2 sensing element failed and did not respond to a high GH_2 concentration.

Figure 1-59. Recent LC-34B Priority I Failures or Problems

1.6.5.2 Saturn IB ESE

The S-IB ESE general test plan was issued in June 1965.

The LC-37B equipment will be tested at Daytona Beach, Florida. To accommodate this equipment, a test facility is nearing completion, with much of the ESE equipment in place. The test plan for LC-37B ESE was issued on 15 October 1965, and will be included in the general test plan at a later date.

A system of reporting on both quality defects and failures has been instituted which will contribute valuable information for the reliability assessment of the equipment.

1.6.5.3 ESE - Systems Development Breadboard Facility (SDBF)

The System Development Breadboard Facility is being modified and updated to reflect the latest vehicle changes and to correct errors. The ESE was connected to the various stage simulators and was powered up. The various failures and discrepancies found in the ESE and simulators are being resolved on a continuing basis.

The RCA 110A Computer Systems downtime has decreased considerably with only 2.8 hours attributed to the actual computers for October. The paper tape reader/ punch cabinet was removed from the LCC computer room. This will provide space for the redundant data link system which will be supplied by RCA.

The lack of spare parts in the RCA 110A and DEE-6 areas has resulted in excessive equipment downtime.

SECTION 2: APOLLO-SATURN V MISSIONS

2.1 GENERAL

2.1.1 SUMMARY

Apollo-Saturn V reliability program activity during this report period began to focus on AS-501. The MSFC updated the 501 launch vehicle reliability predictions, and MSC released the mission definition for spacecraft 017. Reliability activity specifically related to AS-504 consisted in the main of Apollo Program Office mission analyses, GOSS studies and launch availability analyses. Major Apollo-Saturn V program developments during this quarter included:

a. S-II Stage predictions declined reflecting the current stage development problems.
b. Concern became evident over the reliability demonstration requirements for the S-IVB restarts.
c. Modifications in the IU design are reflected in improved reliability predictions.
d. Over-all launch vehicle component qualification test status (as of 31 October 1965) was 32 percent behind schedule.
e. Clarification of the ground rules eliminating ruptures and major leaks (of tubing assemblies, rigid duct assemblies, and pressure vessels) as failure modes on the S-IC has been obtained (refer to paragraph 2.2.2).
f. The LEM Super Weight Improvement Program (SWIP) has resulted in a weight reduction of 113 pounds since the GAEC 1 October report.
g. GAEC reports that Bell Aerosystems has introduced an undersized bladder design which appears to have solved the bladder cycling problem.
h. The N_2O_4 oxidizer utilized in the LEM reaction control system is apparently incompatible with the titanium alloy of the reaction control tanks. This is currently the subject of concerted effort by MSC and all concerned spacecraft contractors.
i. The current Apollo Program Office estimate for AS-504 mission success probability is 0.54. The current Apollo Program Office estimate for crew safety (AS-504 mission) is 0.98.
j. Based upon Apollo Program Office analyses, the major contributor to AS-504 mission unreliability is considered to be the command service module. The major contributor to CSM unreliability is the guidance, navigation, and control system.

2.1.2 APOLLO SATURN 501 MISSION

Saturn V reliability program activity concentrated upon SA-501 during this quarter. Launch vehicle predictions for all stages were updated by the Saturn V Project Office. The S-IC prediction remained constant throughout the quarter; the S-II stage prediction declined reflecting current S-II stage development problems; the S-IVB prediction also declined slightly; and the Instrument Unit's predicted reliability increased due to adoption of an inherently more reliable design configuration. SA-501 criticalities were also reviewed and evaluated during this report period. Revisions to the current criticalities will be reported in the next issue of the "Saturn V Reliability Analysis Model SA-501."

Although CSM reliability activity continued to concentrate upon the 200-series missions, the mission definition and FMEA's for spacecraft 017 (AS-501 mission) were released.

LEM Test Article 10 will be refurbished and utilized as the flight article for the AS-501 mission.

2.1.3 APOLLO-SATURN 504 MISSION

2.1.3.1 Apollo-Saturn 504 Reliability Analysis

2.1.3.1.1 Introduction

The current reliability status of the Apollo-Saturn 504 flight mission and systems reflects changes in system and mission information and consequent effects on the probabilities of crew safety and mission success and of associated technical problems.

The design reference mission reliability profile and major operational ground rules used in this analysis are identical to those employed for the last quarterly report. The reliability data employed in these analyses are recognized as being generic in nature inasmuch as specific design releases for all stages and modules have not been accomplished. This data, however, represents the most up-to-date information available from Centers and contractors on configuration, operational use, and quantitative reliability.

Updated Systems - The systems on which new information has become available are listed in Figure 2-1. This information was categorized into four general classes in order to describe the degree of updating accomplished for a given system.

New information on four of the updated systems (LEM ascent propulsion, LEM descent propulsion, LEM reaction control, and LEM electrical power) was obtained from analysis results generated at the Manned Spacecraft Center in accordance with the concept of the compatible family of models described in NASA OMSF, "Apollo Reliability Analysis and Estimation Guidelines," RA006-007-1, dated November 1965. Thus, the results of a relatively detailed reliability analysis on the major subsystem level (Level 2 model) served as inputs to the analysis at the spacecraft module and mission level (Level 1 model). This first experience in implementation of the compatible family of models concept, while on a small scale, showed the practicability of this concept. Changes in text and illustrations were made corresponding to new information referenced as required. The description of the Ground Operational Support System (GOSS) elements considered in this analysis is summarized and precedes the description of results obtained from analysis work accomplished during this reporting period. Prelaunch, launch availability, and crew/system recovery and retrieval after touchdown are not included in this analysis.

No.	System	Reliability Data	System Ground Rules	System Operational Profile	Logic Diagram
1	CSM Guidance, Navigation, and Control	Updated Reliability Predictions	Unchanged	Unchanged	Improved system representation
2	CSM Environmental Control System and Waste Management	Updated Reliability Predictions and Apportionments	← New (contractor) information on Waste Management System		Updated ECS Logic →
3	CSM Electrical Power	Unchanged	Unchanged	Unchanged	Improved representation of equipment operation
4	LEM Portable Life Support	Updated Reliability Predictions and Apportionments	← All new (contractor) information →		
5	LEM Ascent Propulsion	← Updated per Level 2 Analysis Output →			
6	LEM Descent Propulsion	← Updated per Level 2 Analysis Output →			
7	LEM Reaction Control	← Updated per Level 2 Analysis Output →			
8	LEM Electrical Power	← Updated per Level 2 Analysis Output →			
9	LEM Communications	Updated Reliability Predictions	Modified	Unchanged	Improved system representation
10	S-IC Stage	Updated Reliability Predictions	Unchanged	Unchanged	Improved system representation
11 12	S-II Stage S-IVB Stage	Unchanged	Unchanged	Unchanged	Improved system representation
13	Instrument Unit	← All new (contractor) information →			Improved system representation
14	Ground Operational Support	Unchanged	Manned Space Flight Network Coverage and Space Vehicle Interface Analysis		

Figure 2-1. Updated Apollo Saturn 504 Systems

2.1.3.1.2 Apollo-Saturn 504 System Reliability

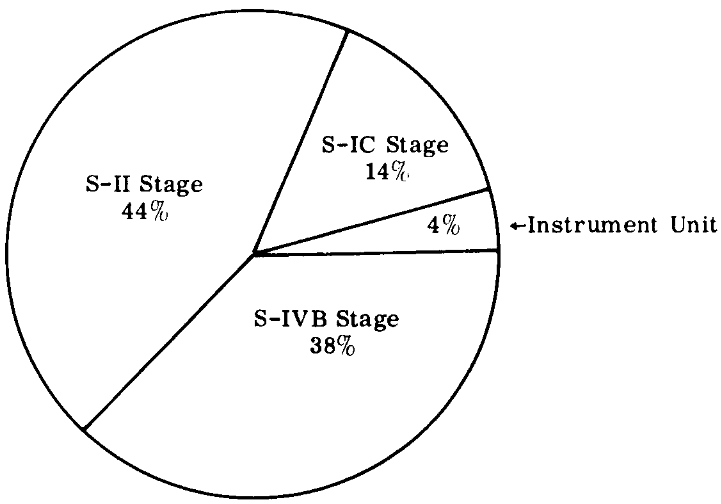
The Saturn V launch vehicle, Apollo spacecraft, and the GOSS reliability aspects of the postlaunch portion of the Apollo-Saturn 504 mission are summarized in subsequent paragraphs.

Saturn V Launch Vehicle - The Saturn V launch vehicle is composed of the S-IC, S-II, S-IVB, and IU stages. The current over-all launch vehicle success probability estimate based on Center/contractor reliability prediction data is 0.78 and reflects the effect of redundancy provided for functions of the IU by guidance equipments of the Apollo spacecraft. This value compares with an estimate of 0.76 reported previously and the apportionment value of 0.85 stated in the Saturn V program development plan.

The J-2 engines in the S-II stage are the greatest contributors to launch vehicle unreliability, primarily because of the relatively long operating time of the five engine subsystems during the mission (all five engines must operate concurrently). Other equipments which stand out significantly as main contributors to the launch vehicle unreliability are the auxiliary propulsion engines and a selector switch in the electrical power system of the S-IVB stage.

Figure 2-2 shows relative contributions of each stage to the predicted launch vehicle unreliability. Figure 2-3 shows the predicted launch vehicle and stage success probabilities as a function of mission phase.

Apollo-Saturn 504 Manned Lunar Landing Mission
Launch Vehicle



Notes: 1. The Launch Vehicle accounts for 41 percent of the total mission unreliability.

2. Ground Operational Support System and Crew Functions were considered to have a reliability of 1.0 for this study.

Figure 2-2. Percentage Contribution of Stages to Launch Vehicle Unreliability

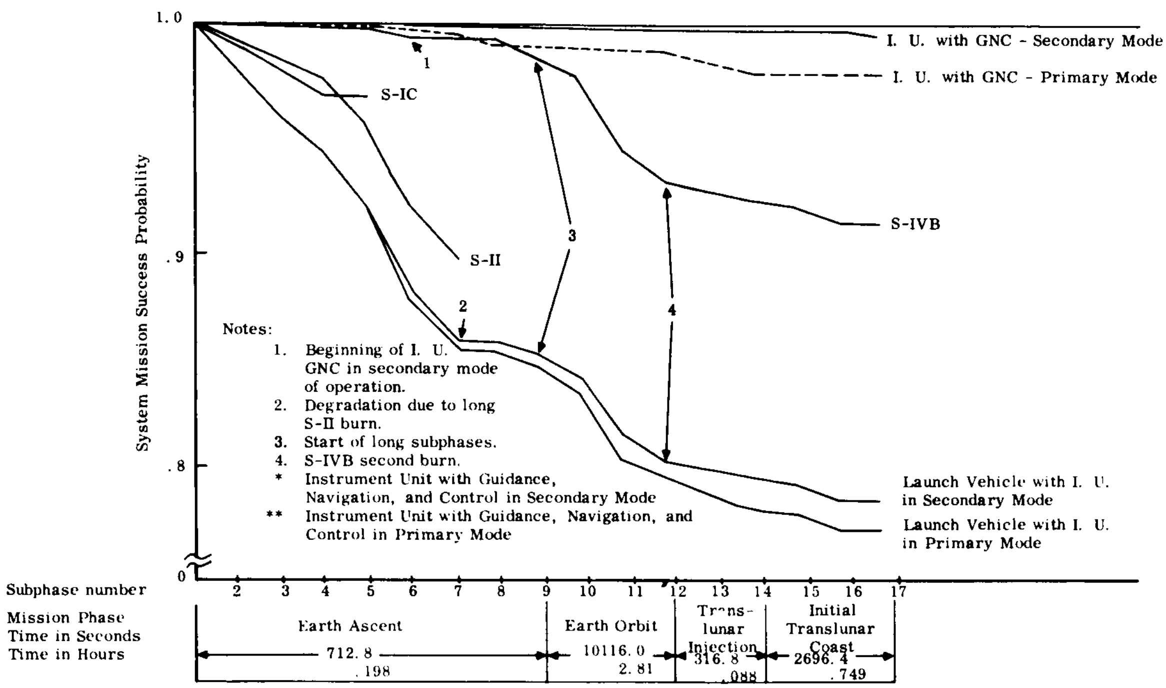


Figure 2-3. Predicted Launch Vehicle and Stage Mission Success Probabilities versus Mission Phase

Spacecraft - Approximately fifty-nine percent of the total mission unreliability is due to the spacecraft. With this percentage taken as a base, the command service module contributes sixty-six percent and the lunar excursion module contributes thirty-four percent to spacecraft unreliability. Of all spacecraft systems and launch vehicle stages, the command service module guidance, navigation and control subsystem ranks first with a percentage contribution to predicted over-all mission unreliability of 17.6 percent.

Figure 2-4 illustrates command service module and lunar excursion module mission success probabilities by major mission phases to identify periods of significant decrease of mission reliability.

The system logic and data used in this analysis were assembled from available program information and have not been reconciled in all cases with information available to the contractors. As the program of analytical model reviews progresses, variations between contractor and Apollo Program Office estimates will decrease or at least be clearly identifiable.

Command Service Module (CSM) - The CSM contributes thirty-nine percent to mission unreliability. Figure 2-5 shows the percentage contribution of systems to CSM unreliability. The current Center/contractor reliability apportionment and prediction values for the CSM are 0.96 and 0.94, respectively, where the CSM over-all apportionment is based on the combination of CSM subsystem apportionments. The Apollo Program Office estimate of CSM mission success probability based on Center/contractor subsystem predictions is 0.78.

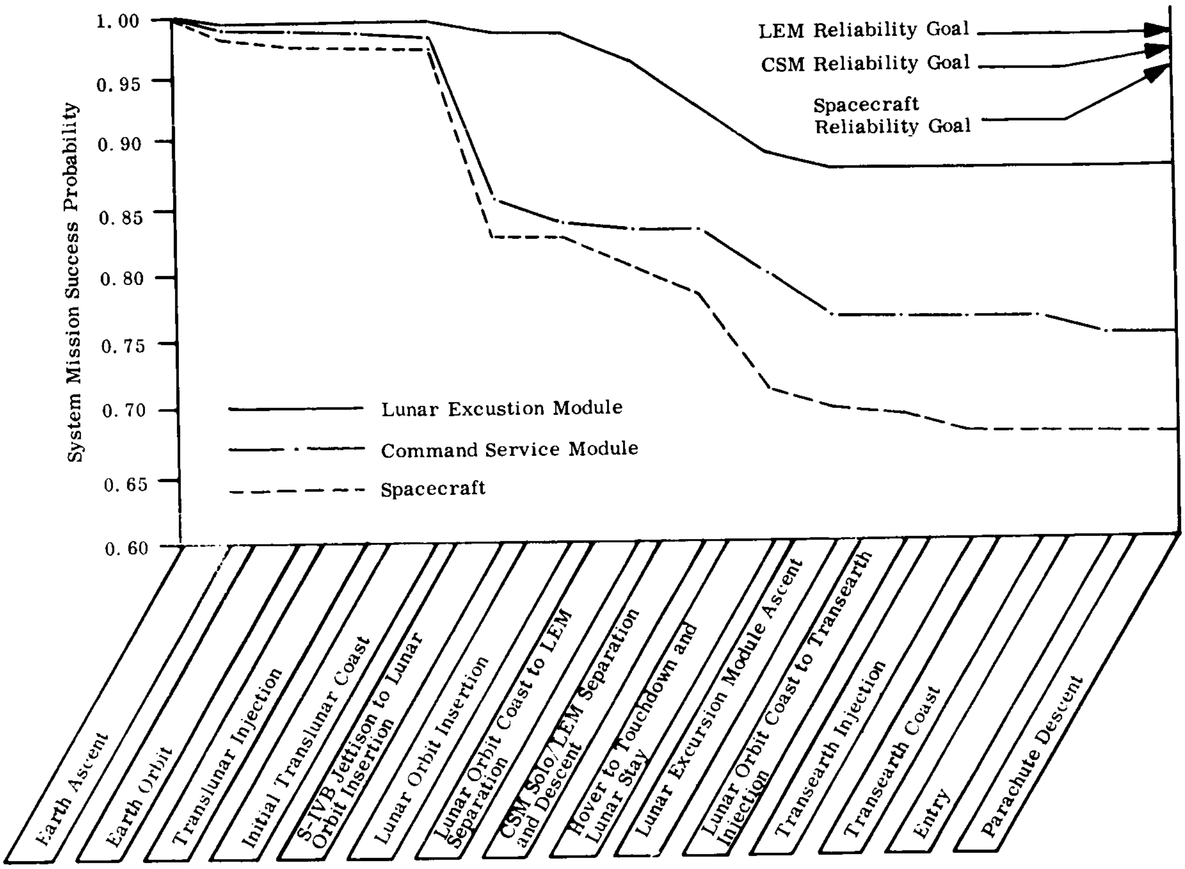
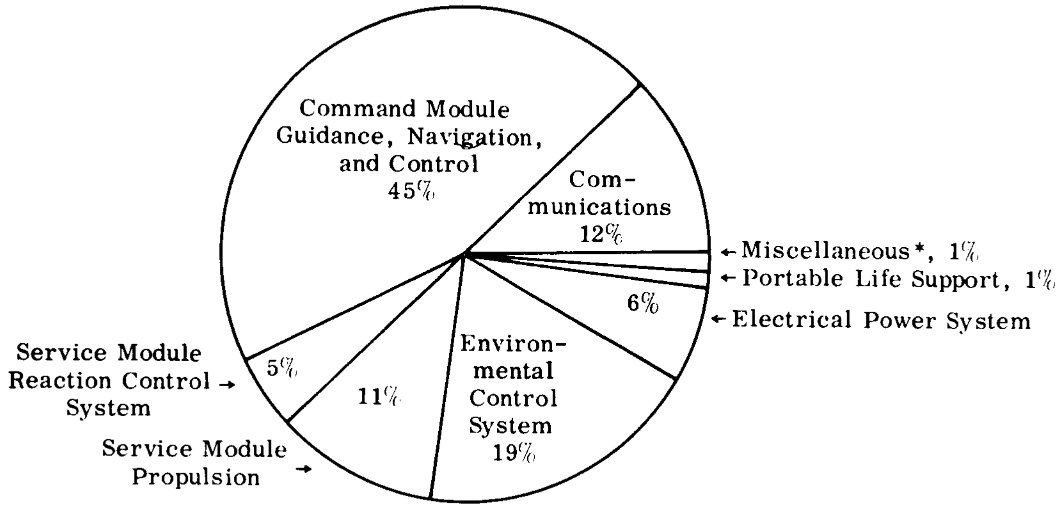


Figure 2-4. Predicted Spacecraft System Probabilities of Mission Success versus Mission Phase

Apollo-Saturn 504 Manned Lunar Landing Mission
Command and Service Module



*Miscellaneous includes Emergency Detection System, Docking Mechanism, Earth Impact and Flotation, Parachute Recovery, Separation System, Launch Escape System, Heat Shield, Structure, Command Module Reaction Control System and Cryogenic Storage.

Notes: 1. The Command Service Module accounts for thirty-nine percent of total mission unreliability.

2. Ground Operational Support System and Crew Functions were considered to have a reliability of 1.0 for this study.

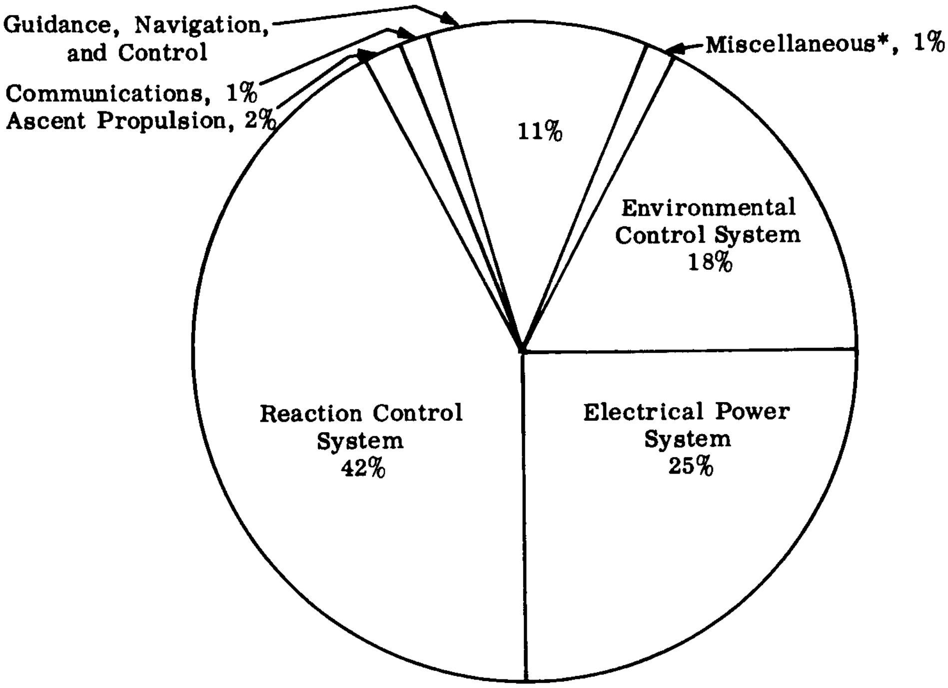
Figure 2-5. Percentage Contribution of Systems to Command Service Module Unreliability

<u>Lunar Excursion Module (LEM)</u> - The LEM contributes twenty percent to predicted over-all mission unreliability. Figure 2-6 shows the percentage contribution of systems to LEM unreliability.

Center/contractor apportionment and prediction values for the LEM are 0.99 and 0.87, respectively. The current Apollo Program Office estimate of LEM mission success probabilities based on Center/contractor predictions is 0.88. The reason for the current discrepancy between the Apollo Program Office and the Center/contractor reliability prediction is the predicted value of reliability of the LEM reaction control system from the (Level 2) Manned Spacecraft Center reliability computation. This discrepancy has been referred to the Manned Spacecraft Center for resolution. Manned Spacecraft Center, Level 2 analysis outputs on the LEM ascent and descent propulsion systems, LEM electrical power system, and the LEM reaction control system were used for updating the Apollo Program Office reliability predictions. Information received after completion of the current analysis affects the LEM reliability status. These recent changes are discussed in paragraph 2.7 of this report.

Apollo-Saturn 504 Manned Lunar Landing Mission

Lunar Excursion Module



*Miscellaneous includes Structures, Instrumentation, and Pyrotechnics. Its percentage is negligible.

Notes:
1. The Lunar Excursion Module accounts for twenty percent of total mission unreliability.
2. Ground Operational Support System and crew functions were assumed to have a reliability of 1.0 for this study.

Figure 2-6. Percentage Contribution of Systems to Lunar Excursion Module Unreliability

2.1.3.1.3 Ground Operational Support System (GOSS)

GOSS is composed of the Manned Space Flight Network (MSFN) and the Control Centers. It is an information transportation system supporting the communications and tracking capabilities of the space vehicle. Communications between the MSFN and the space vehicle consist of various combinations of voice, telemetry, up-data, television, and ranging information multiplexed on the transmission carrier frequencies. Equipments and facilities currently not used for support of space flight missions are to be employed for the Apollo-Saturn 504 mission and include the unified S-band system, instrumented aircraft and communications satellites.

The Apollo Program Office has initiated a reliability analysis of the GOSS during this reporting period. The initial objectives of this analysis are (1) to determine the functional interrelationships between GOSS and the space vehicle and (2) to determine how this interrelationship affects the over-all mission reliability.

Charts have been prepared summarizing and exhibiting planned Apollo-Saturn 504 mission-type GOSS coverage as extracted from Apollo Program documentation currently available for analysis. The charts show for each stage and module of the Apollo-Saturn V space vehicle, communications, and tracking requirements on the MSFN as a function of nominal mission time per the design reference mission reliability profile.

The charts also identify the particular GOSS station planned to provide a given mission essential function at any given time point in the nominal mission. Associated GOSS station equipment logic diagrams and indenture lists are also in preparation.

The relative frequencies, with which the spacecraft guidance and navigation system requires immediate Manned Space Flight Network (MSFN) availability for abort initiation, have been computed for selected phases in the (nominal) mission. Results will be included in a report to be issued during the first quarter of 1966.

The mission-essential functions supported by the MSFN are the transmission of information. This involves carriers (the transmission system) and signals (the information). It is therefore not sufficient to analyze the individual transmission links; an MSFN mission reliability analysis must consider the signal, the transmission links, and their interactions along the entire signal flow path from source to signal utilization.

For Apollo-Saturn 504 reliability predictions, Center/contractors, and the Apollo Program Office have consistently assumed 1.0 for the reliability of GOSS functions. However, GOSS support of a manned lunar landing mission is limited to the number of available deep-space and near-earth ground stations, but continuous spacecraft monitoring for contingencies is required. In view of these factors, the estimate of 1.0 is overly optimistic, and a decrease in both mission success and crew safety probabilities should be expected when GOSS reliability data is factored into the analysis.

Contents of documents analyzed to date do not agree with one another on all points concerning the MSFN nor do they present sufficient evidence to assure availability of support of mission essential functions for the Apollo-Saturn 504 mission.

2.1.3.1.4 Launch Availability

During this quarter, a search was conducted to determine the availability of "time-to-failure" and "time-to-restore" data for Apollo mission-essential equipment during the prelaunch phase of mission. Because this data was not available, previous countdowns were analyzed for application to the Apollo program. A summary of this historical data analysis is presented below.

Using a high-level analytical simulation model, a parametric analysis of the prelaunch phase was initiated to determine the probabilities of launch, based on best, nominal, and worst-case failure rates and time-to-repair data. The results of the parametric analysis will be available during the first quarter of 1966.

Historical Data - The countdown data from 105 scrubs and 169 launches from Cape Kennedy were analyzed:

a. "Studies on Manpower Requirements for Rocket Booster Launch Operation," Volume II, May 1965, by TRW/STL, Florida Operation.

b. "Launch Probability Analysis in Support of Gemini, Early Rendezvous Study," Volume 3, May 1965, by TRW/STL, Florida Operation.

The vehicles consisted of 60 Atlas R&D, 29 Atlas space vehicles, 70 Titan, and 10 Saturn I series vehicles. Particular data analyzed were number of holds, countdown time at scrub, cause of scrub, and excess time. Excess time is defined as the hold time and any associated recycle time which causes a launch to occur beyond T -0, the planned nominal launch time.

Analysis - An analysis was made of the excess time on 169 successful countdowns. This analysis is reflected in Figure 2-7.

Apollo-Saturn 504 Manned Lunar Landing Mission
Launch Availability Analysis
Historical Analysis of
169 Previous Successful Countdowns at KSC

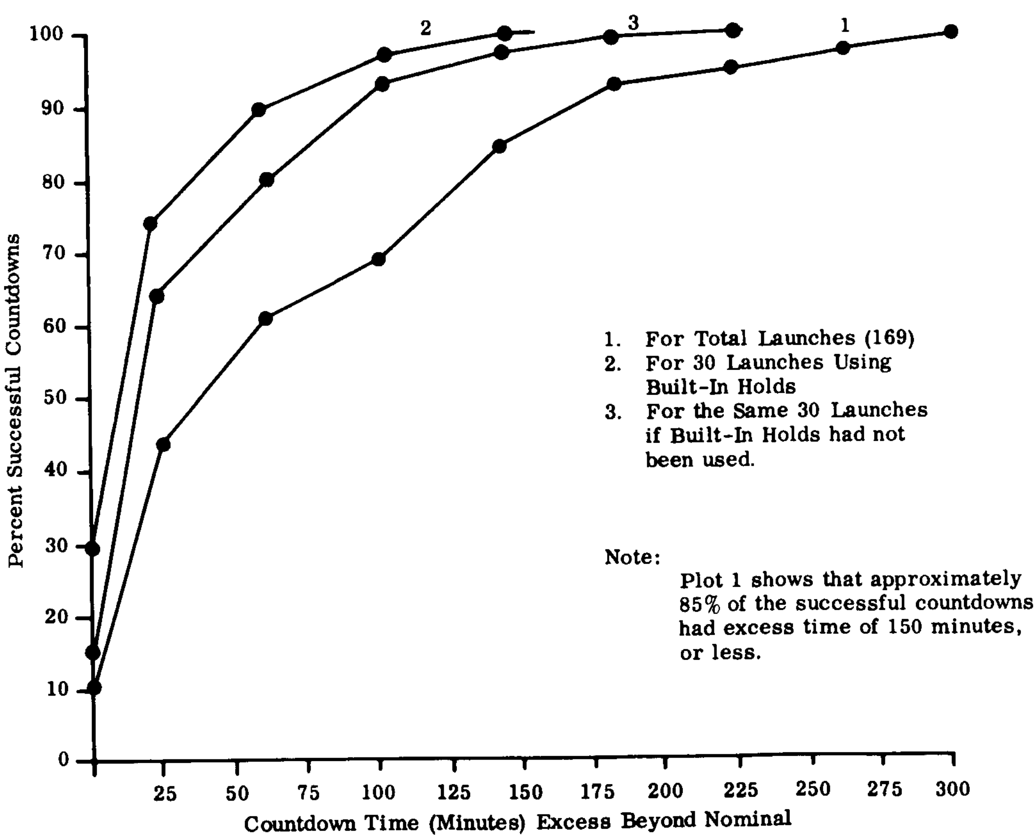


Figure 2-7. Percent Successful Countdowns versus Countdown Time Excess Beyond Nominal

An analysis was made to determine the distribution of holds called during the 169 successful countdowns. The results are shown in Figure 2-8. Of the total holds (442), only 19 were of such a nature (weather and ship in down-range area) that no repairs were needed before the hold could be terminated.

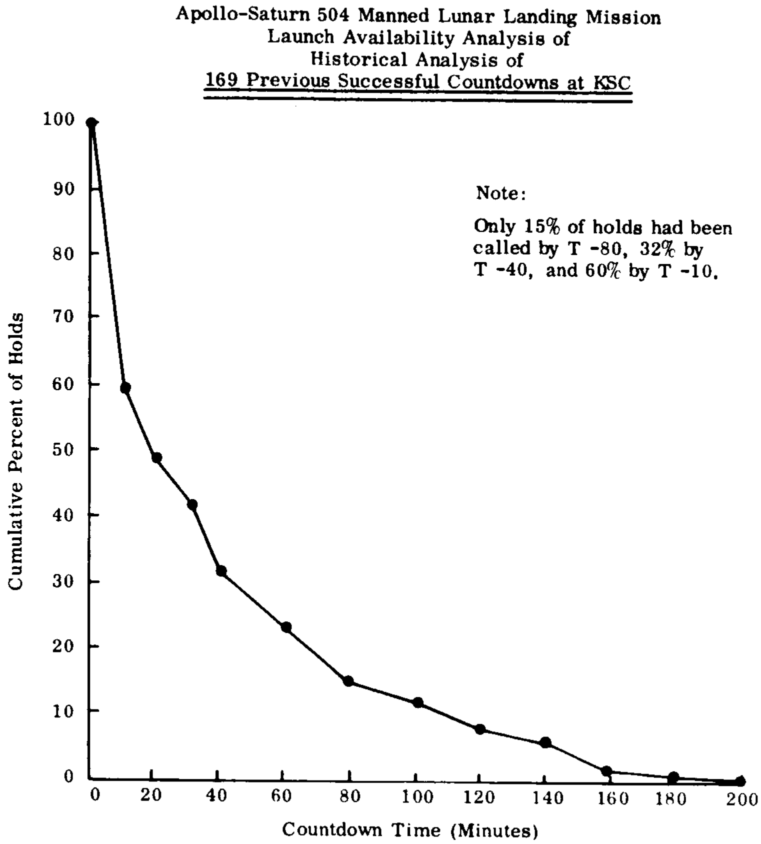


Figure 2-8. Cumulative Percent of Holds versus Countdown Time for Successful Countdowns (169 Launches, 442 Holds)

<u>Conclusions</u> -

a. 95 percent of the holds which occur are time-to-restore holds.
b. 61.6 percent of the total countdowns resulted in launch.
c. Countdowns with built-in holds had less excess time (at launch or scrub) than did those without built-in holds.

2.1.3.1.5 Crew Safety and Mission Success

This analysis relates probabilistic measures of mission/system reliability effectiveness to the fifteen major phases of the design reference mission and to Apollo-Saturn V space vehicle systems making the largest contribution to mission unreliability.

The launch vehicle and spacecraft contribute about 41 percent and 59 percent, respectively, to the total unreliability for the Apollo-Saturn 504 mission. The operational mission time of the launch vehicle, however, is only about three hours compared to 198 hours for the spacecraft. Thus, the unreliability contributions are 13.6 and 0.3 percent per mission hour for the launch vehicle and spacecraft, respectively.

The command service module is still the leading contributor to total mission unreliability (see Figure 2-9). The logic of the mission simulation was updated to take advantage of equipment redundancy in the command service module environmental control system. This reduced the criticality of the transearth-coast phase, with respect to the probability of crew loss, from first to third rank. The two most hazardous mission phases are the hover to touchdown and lunar stay phase, and the S-IVB jettison to lunar orbit insertion phases.

Apollo-Saturn 504 Manned Lunar Landing Mission
Apollo-Saturn V Space Vehicle

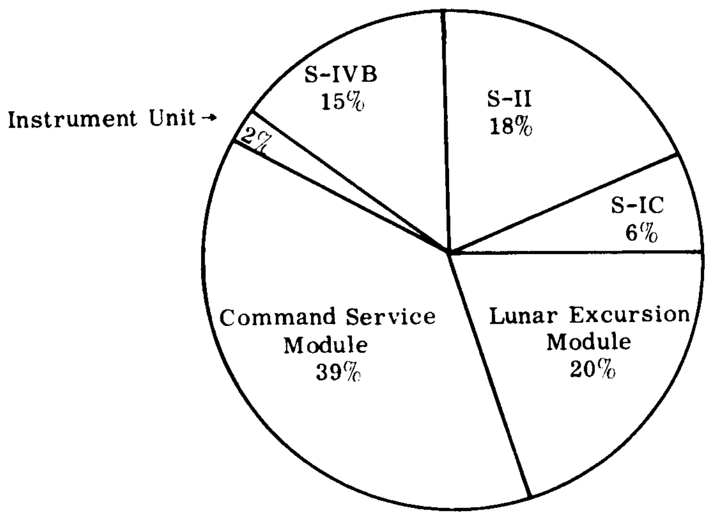


Figure 2-9. Percentage Contribution of Stages and Modules to Total Mission Unreliability

A decrease in S-IC stage success probability, based on updated Center/contractor reliability prediction data, causes the earth ascent phase to rank first and the S-IVB jettison to lunar orbit insertion phase to rank second with respect to the probability of mission loss. However, the probability of crew loss in the earth ascent phase is considerably less than in the S-IVB jettison to lunar orbit insertion phase.

The phase criticality rank order by contribution to mission unreliability and by safety hazard are shown in Figures 2-10 and 2-11, respectively.

The general assumptions applied to the equipments and functions in the formulation of the Apollo-Saturn 504 mission simulation model were the same as those listed in the previous report.

Apollo-Saturn 504 Manned Lunar Landing Mission		
Mission Phase	Leading System Contributor to Mission Phase Unreliability	Rank by Phase Contribution to Mission Unreliability
Earth Ascent	S-II Stage	1
S-IVB Jettison to Lunar Orbit Insertion	CSM Guidance, Navigation, and Control	2
Earth Orbit	S-IVB Stage	3
Hover to Touchdown and Lunar Stay	LEM Electrical Power	4
Lunar Orbit Coast to LEM Separation	LEM Reaction Control	5
CSM Solo/LEM Separation and Descent	LEM Reaction Control	6
Initial Translunar Coast	S-IVB Stage	7
Lunar Excursion Module Ascent	LEM Reaction Control	8
Translunar Injection	S-IVB Stage	9
Transearth Coast	CSM Environmental Control	10
Lunar Orbit Coast to Transearth Injection	CSM Guidance, Navigation, and Control	11
Lunar Orbit Insertion	Service Propulsion	12
Entry	CM Reaction Control	13
Transearth Injection	Service Propulsion	14
Parachute Descent	CM Parachute	15

Figure 2-10. Mission Phase Criticality Rank by Contribution to Mission Unreliability

Apollo-Saturn 504 Manned Lunar Landing Mission		
Mission Phase	Leading System Contributor to Mission Phase Unreliability	Rank by Relative Safety Hazard
Hover to Touchdown and Lunar Stay	LEM Electrical Power	1
S-IVB Jettison to Lunar Orbit Injection	CM Environmental Control	2
Transearth Coast	CSM Environmental Control	3
Lunar Excursion Module Ascent	LEM Guidance, Navigation, and Control	4
Lunar Orbit Insertion	Service Propulsion	5
Lunar Orbit Coast to LEM Separation	CM Guidance, Navigation, and Control	6
CSM Solo/LEM Separation and Descent	LEM Guidance, Navigation, and Control	7
Lunar Orbit Coast to Transearth Injection	CM Guidance, Navigation, and Control	8
Earth Orbit	CM Guidance, Navigation, and Control	9
Entry	CM Reaction Control System	10
Transearth	Service Propulsion	11
Earth Ascent	S-IC Stage, S-II Stage, Launch Escape, Parachute*	12
Initial Translunar Coast	Service Propulsion and CM Guidance, Navigation, and Control*	13
Parachute Descent	CM Parachute	14
Translunar Injection	None	15

*Equal Percentages

Figure 2-11. Mission Phase Criticality Rank by Relative Safety Hazard

Systems of Unknown Reliability - Systems, equipments, or functions for which reliability data were unavailable were assigned a reliability of 1.0. These include the following:

a. Flight crew functions.
b. Ground operational support system functions.
c. Oxygen supply (descent) - lunar excursion module environmental control.
d. LiOH cartridge-lunar excursion module environmental control.
e. Portable life support system cartridge-lunar excursion module environmental control.
f. Ground support equipment disconnect-lunar excursion module environmental control.
g. Line of sight/velocity indicator-lunar excursion module guidance and control.
h. LiOH cannister check valve-command service module environmental control.
i. Backup roll attitude display-command service module guidance, navigation, and control.
j. Entry monitor display-command service module-guidance, navigation, and control.

Reliability Apportionment and Prediction Estimates - Apollo Program Office estimates of crew safety and mission success probabilities, based on current Center/contractor reliability predictions, are 0.98 and 0.54, respectively. Based upon current Center/contractor reliability apportionments, the estimates for these two probabilities (the apparent goals) are 0.99 and 0.81, respectively.

Over-all mission success and crew safety probabilities versus mission time are shown in Figure 2-12.

2.1.3.2 Reliability Program

2.1.3.2.1 Qualification Test Summary

The status of the Apollo-Saturn V component qualification test program as of 31 October 1965 is depicted in Figure 2-13. It should be noted that component qualification status information was not available for the spacecraft or Apollo-Saturn V ancillary equipment. For the over-all launch vehicle, component qualification status of 31 October 1965 was 32 percent behind schedule.

2.1.3.2.2 Reliability Assurance

Figure 2-14 describes the degree to which NPC 250-1 was contractually required and implemented on the Saturn V (as of 9 October 1965). This presentation would indicate that CSE is in serious arrears as regards NPC 250-1 implementation. No information was available from either MSC or KSC.

2.1.3.2.3 Ground Support Test

Tests on the LEM descent engine have uncovered several problems affecting reliability. The LEM ascent engine explosion (while under test in the altitude facility at AEDC) is being investigated.

Checkout of the S-IC-1 at the MSFC Qual. Lab is encountering delays due to some stage hardware shortages. First firing of the S-II-T at MTF is being delayed due to repairs to insulation and changes to the stage. Procurement of transducers is the major constraint currently affecting the S-IVB-501 stage.

2.1.3.2.4 Weight Consideration

The LEM weight problem reported in the third quarter R&QA status report has been improved through the LEM weight reduction program. Weight growth was arrested, and a weight reduction of 100 pounds was achieved during this reporting period.

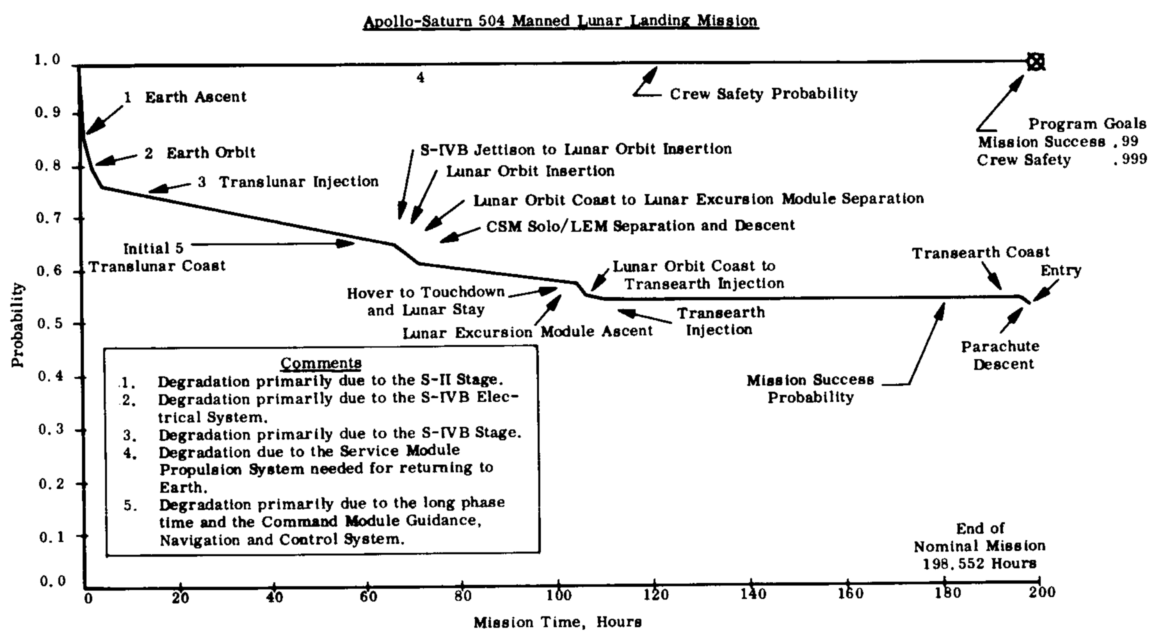


Figure 2-12. Mission Success and Crew Safety Probabilities versus Mission Time

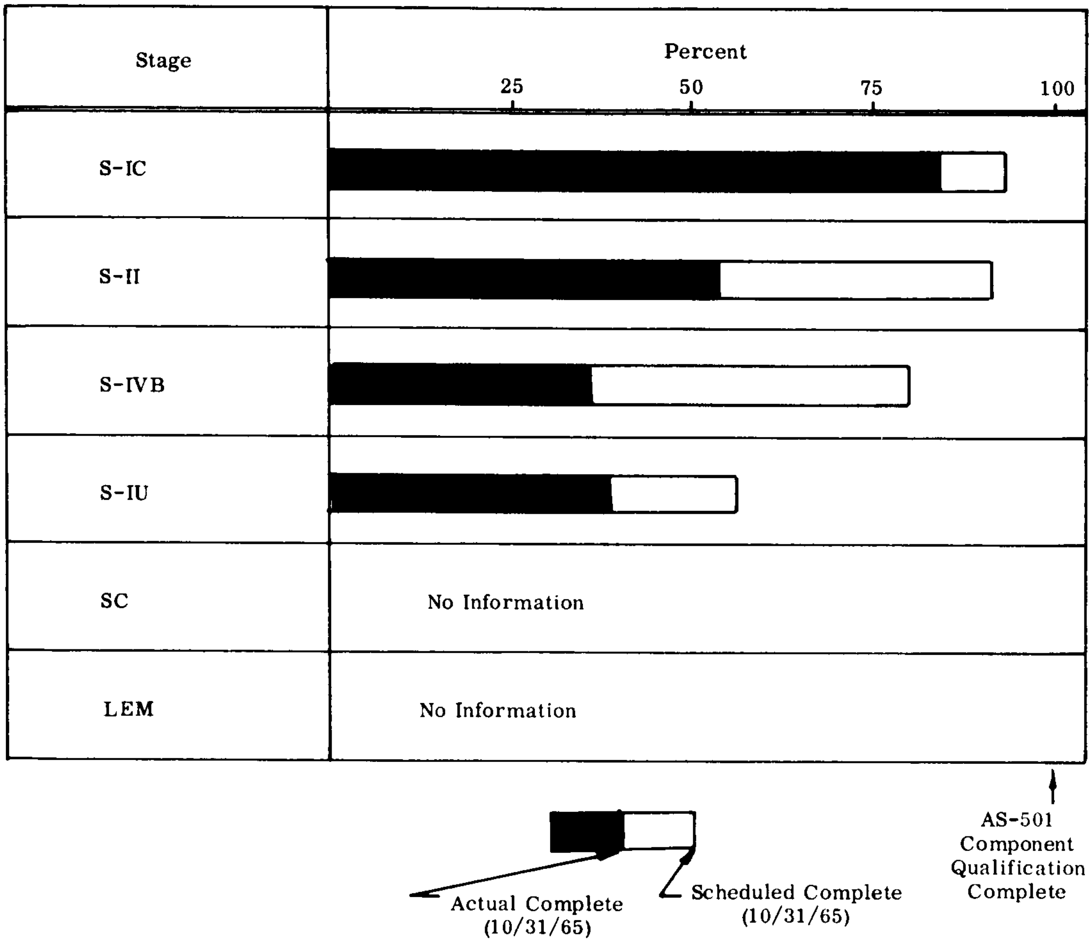


Figure 2-13. Apollo-Saturn V Component Qualification Status

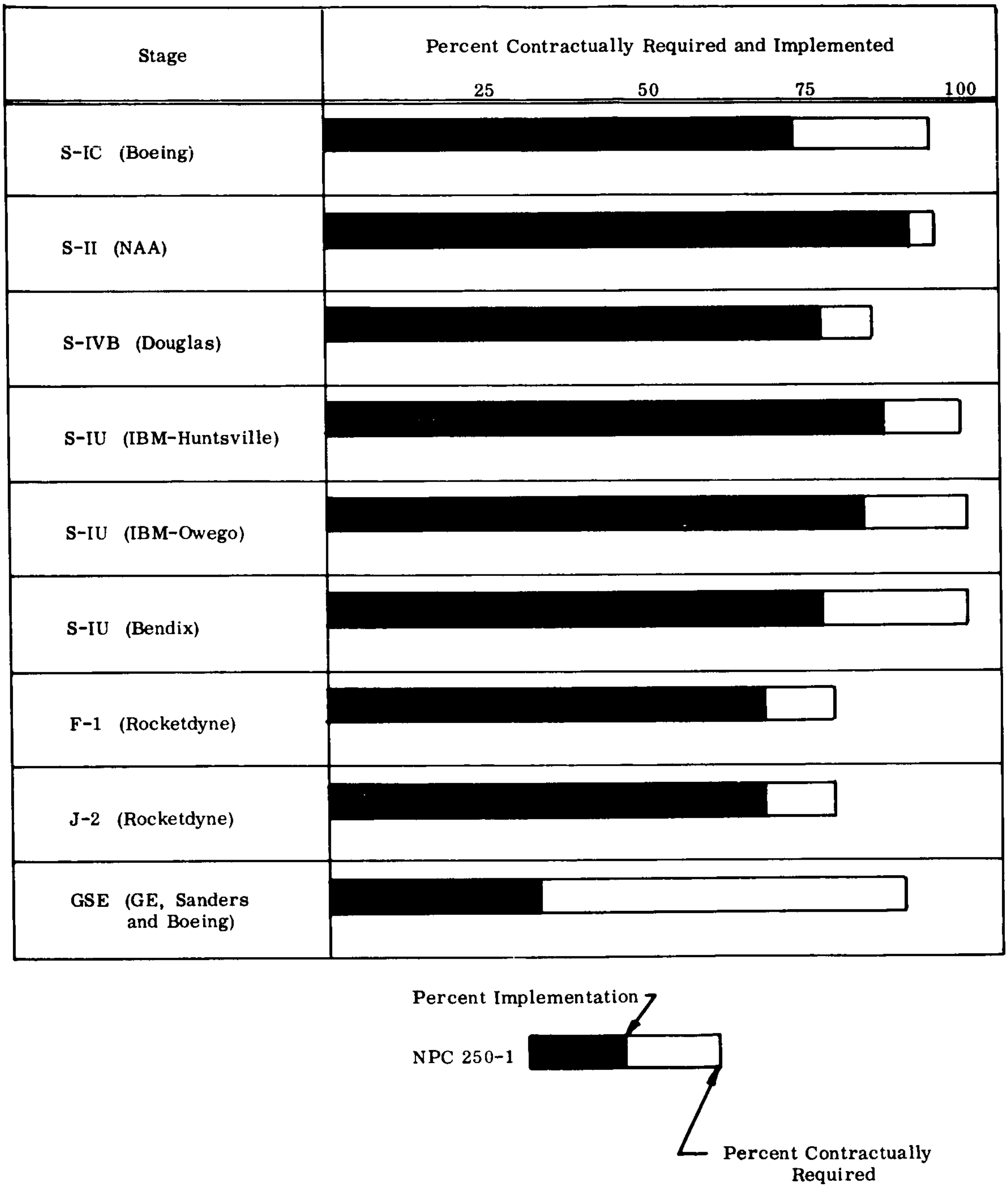


Figure 2-14. Saturn V Program Summary Reliability Assurance Evaluation Based on NPC 250-1

2.2 S-IC STAGE

2.2.1 GENERAL

During this report period, the S-IC stage continued in the ground test phase. The S-IC-1 was transferred to R-Qual for checkout. The S-IC-T was successfully test fired (five engines) for 42.35 seconds. The S-IC-D was delivered to MSFC. Vertical assembly of the S-IC-3 commenced. The S-IC-2 hardware deliveries remained essentially on schedule.

2.2.1.1 Reliability Program

Reliability program status as of 1 October 1965 is shown in Figure 2-15. It is noted that the areas of program management and reliability evaluation have been rated lowest of those elements considered. S-IC program management shortcomings cited by MSFC include the following:

a. Program review schedules are not required.
b. Management control and scheduling are not stipulated as a portion of the program plan.
c. A detailed outline of the training plan has not been required.

The major reliability evaluation shortcoming noted was the fact that the contractor is not required to submit a reliability evaluation plan.

2.2.2 RELIABILITY ENGINEERING

As previously reported, major leaks and failures of gimbals and flex hoses have been eliminated as valid failure modes. The following ground rules were used in preparation of the S-IC failure mode and effect analyses and were agreed upon by representatives of the Boeing Company and MSFC.

Rupture/major leakage of tubing assemblies, rigid duct assemblies, and pressure vessels will not be listed on the FMEA. While it was generally agreed that these failures could occur, in most instances they would be an effect of another failure or an environment not designed for. Furthermore, these items are structural in nature and will come under design assurance techniques used for primary structure such as stress checks, etc.

These analyses will consider failures of certain dynamic components such as flexible hoses, bellows, and similar items of hardware even though, by rigid application of the above ground rule, they might be excepted. Where such failure modes are considered, they will be denoted.

Rupture/major leakage shall be considered at connections only when a third member such as a seal is present. Fittings and flanges per se will not be considered. It is felt that a connection would be structural in nature unless a quasi-dynamic part such as a gasket or O-ring were present and could fail in such a way as to cause loss of fluid.

The above ground rules were chosen to avoid arbitrary standardization regarding quantities of fluid loss. Since there is much uncertainty in the areas of leaks and ruptures, it was felt it would be less restrictive to handle each failure, its frequency ratio and effects as they apply to the system being analyzed.

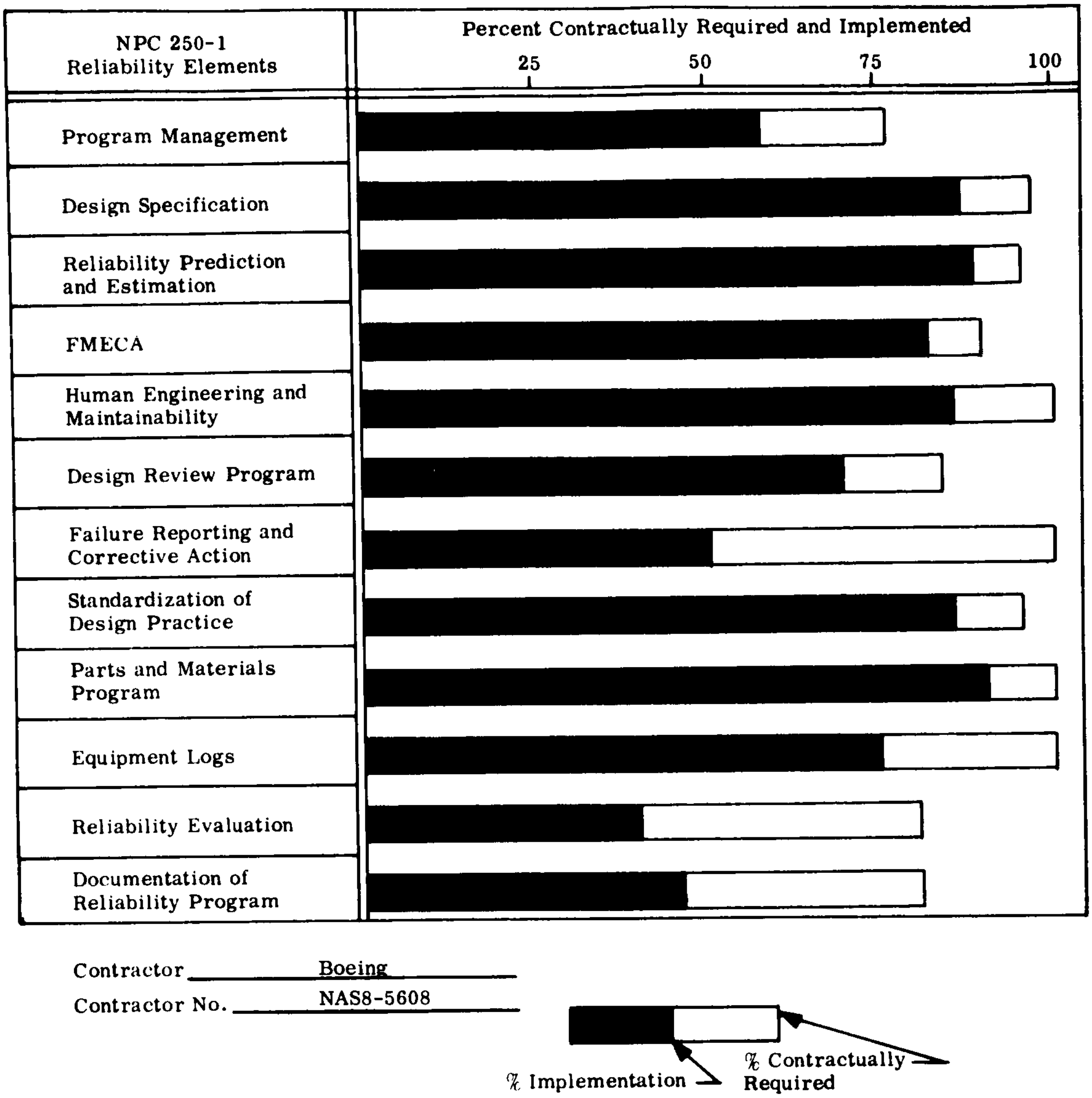


Figure 2-15. S-IC Stage Reliability Assurance Evaluation Based on NPC 250-1

Current analyses of the S-IC-501 propulsion mechanical systems attribute 26 percent of the over-all criticality to failures occurring in countdown and 74 percent of the over-all criticality to failures occurring in flight. The leading causes of vehicle loss are considered to be: loss of thrust vector control, 31 percent; fire or explosion, 31 percent; and retro-rocket explosion, 13 percent. Gimbal joints are classified as the key items of concern. The fluid power and fuel pressurization subsystems are considered most critical contributing 31 and 27 percent of the total criticality, respectively.

The LOX vent and relief valve which exhibited slow closure response was redesigned and has now passed qualification test.

The LOX pressurization system upper GOX ducts which failed during vibration test were redesigned and have now been qualified.

Qualified pressure switches are not available to meet S-IC program schedule demands. Alternatives for factory and static firing interlocks employing manual techniques are being considered. Aerojet has been developed as a back-up source.

Telemetry will not perform in the S-IC environment and is therefore currently undergoing redesign.

S-IC stage design loads continue as a problem. The basic criteria required to establish the design loads are incomplete in the CEI specifications.

2.2.2.1 Critical Parts

The ten most critical items for the S-IC Stage are listed in Figure 2-16. These have been derived from advance information which is expected to appear in the next revision of "Saturn V Reliability Analysis Model SA-501" R-P&VE VOA-65-64 and reflect a change in order from those utilized in the "Saturn V Reliability Analysis Model, SA-501."

Item	Subsystem	Criticality Ranking by Flight Stage			
		S-IC-501			
Retrorocket Motor	Retrorocket	1			
Fuel Prevalve	Fuel Delivery	2			
Engine Control Valve	F-1 Engine	3			
LOX Ducting	LOX Delivery	4			
Gas Generator Ball Valve	F-1 Engine	5			
Slide Duct, Joint Section	Fuel Delivery	6			
Main Oxidizer Valve	F-1 Engine	7			
Gimbal, Duct, LOX	LOX Delivery	8			
Gimbal, Duct, Fuel, Suction	Fuel Delivery	9			
Slide Joint, Duct	LOX Delivery	10			

Items Dropped from Preceding List:

Rank	Item

Figure 2-16. S-IC Stage Ten Most Critical Items

2.2.2.2 Apportionments and Prediction

The S-IC Stage prediction shown in Figure 2-17 reflects the Saturn V prediction as of 1 October 1965.

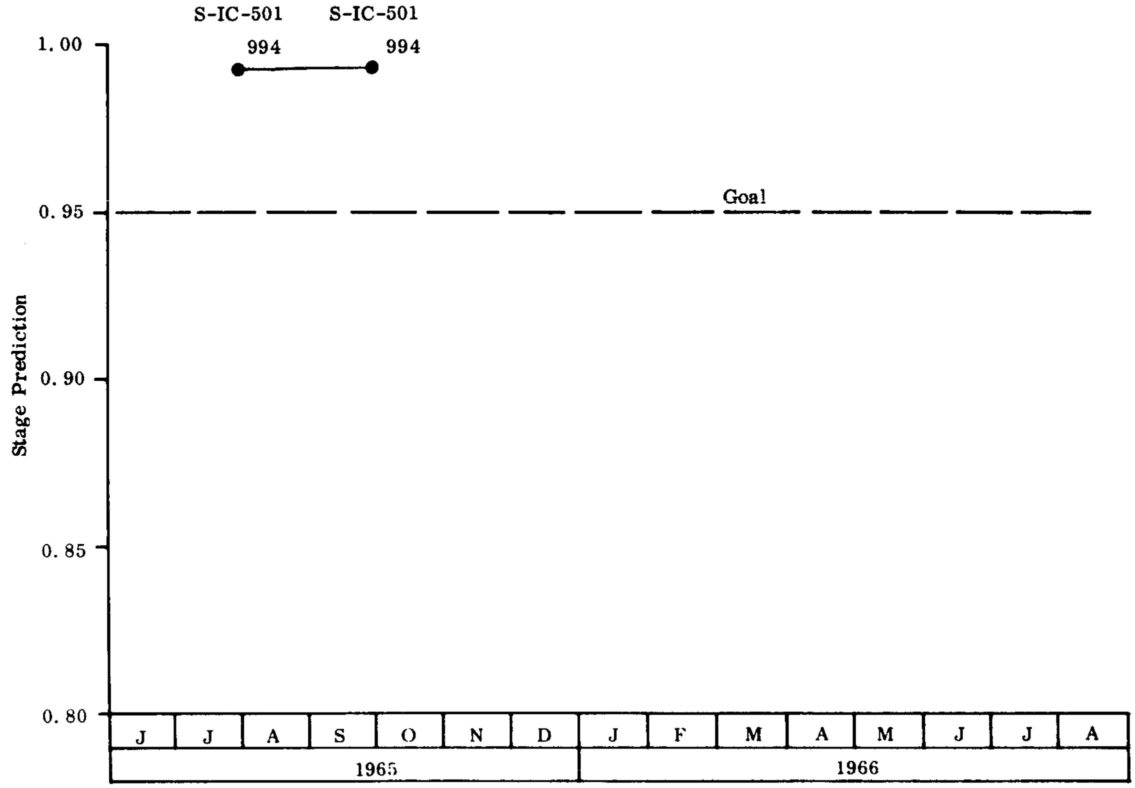


Figure 2-17. S-IC Stage Reliability Trend (Mission Success)

2.2.3 TEST PROGRAM

2.2.3.1 Ground Test Program

The S-IC-1 critical item structural test program is generally proceeding on schedule. However, (1) the LOX tank cruciform baffle failed during slosh, acceleration, and vibration test at 145 percent load limit; (2) the fuel tank cruciform baffle failed test twice; and (3) the outboard and inboard propellant support brackets failed during test. Action is being taken to resolve these difficulties.

2.2.3.2 Qualification Test

The current status of S-IC component qualification testing is shown in Figure 2-18. As of 1 November 1965, 11 percent of the items to be qualified were behind schedule.

2.2.4 QUALITY ASSURANCE

2.2.4.1 Quality Trends

Figure 2-19 shows the cumulative number of critical and major discrepancies for S-IC-1 and S-IC-2 as a function of percent completion. Extrapolation of these curves provides an estimate at completion of 200 discrepancies for S-IC-1 and 125 discrepancies for S-IC-2.

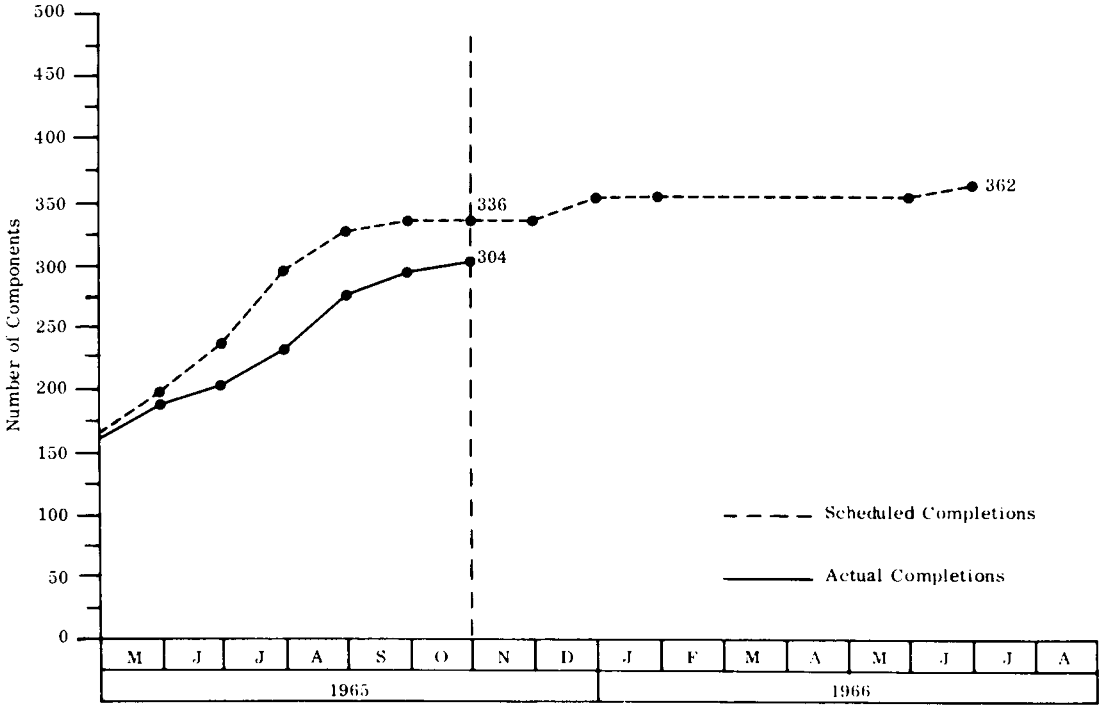


Figure 2-18. S-IC-501 Stage Total Component Qualification

Figure 2-20 shows the trend of F-1 parts discrepant at final assembly. Figure 2-21 shows the trend in discrepancies/malfunctions of F-1 engines at electrical and mechanical inspection.

2.2.4.2 Quality Problems

The major discrepancy encountered during fabrication and assembly has been contamination control. The main factors contributing to the problem are present state-of-the-art and lack of experienced personnel.

Research is being conducted industry-wide, and an evaluation is being made to advance the present state-of-the-art. As advances are made, they are incorporated into operating procedures and further training provided to personnel. Additional training classes are being arranged to provide personnel with continuous training in the present state-of-the-art.

F-1 engines 4018 and 4019 exhibited fewer discrepancies at MSFC reviewing inspection than previous engines.

2.2.4.3 Quality Program

Figure 2-22 shows the status of the S-IC quality program as of September 1965 based on NPC 200-2.

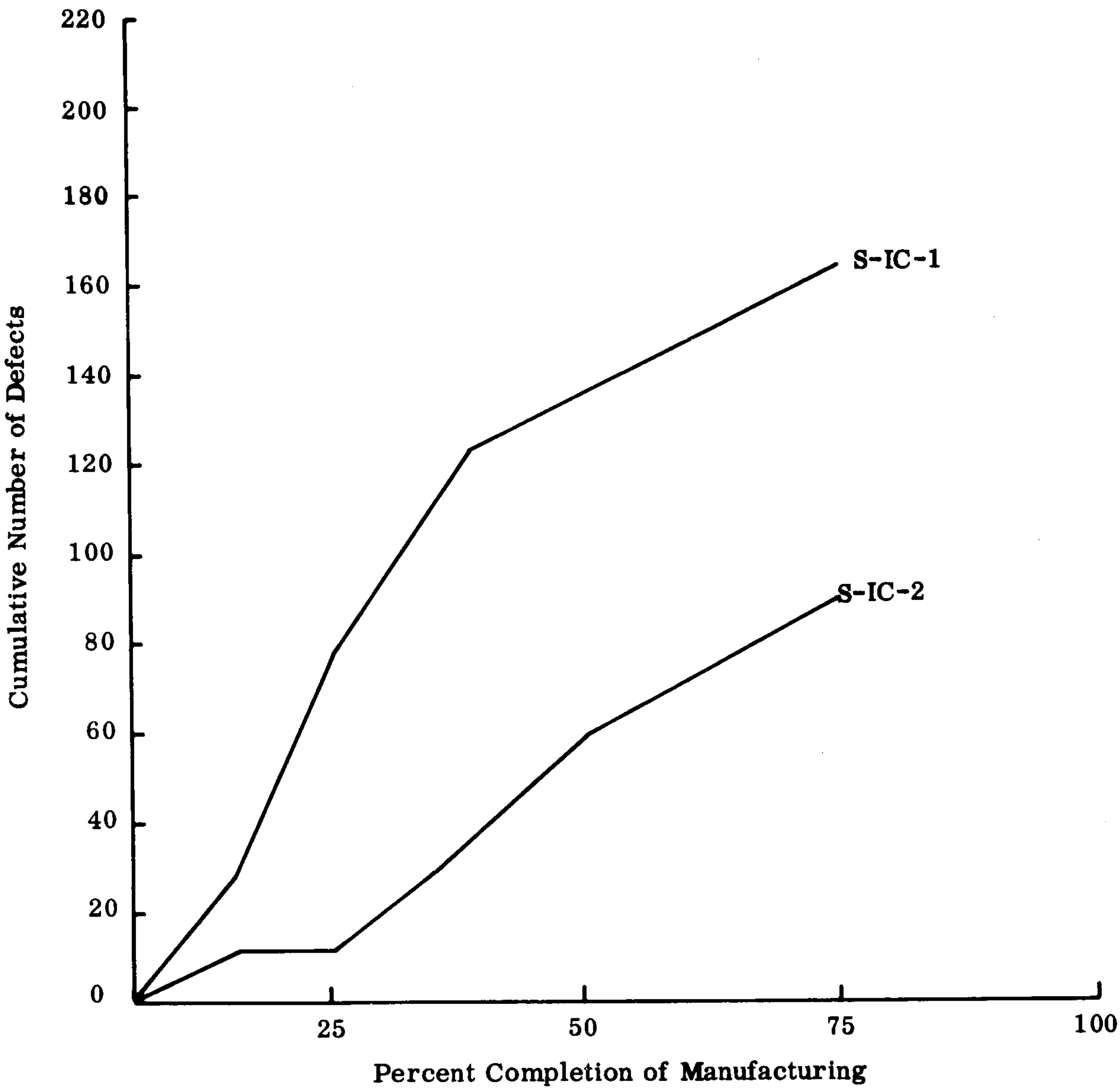


Figure 2-19. S-IC Stage Critical and Major Manufacturing Discrepancies as of 1 September 1965

2.3 S-II STAGE

2.3.1 GENERAL

The major problems facing the S-II stage are the insulation bonding problem and the failure of the S-II-S during the structural test. Failure occurred during S-II-S structural testing at a pressure lower than the design pressure and in an unanticipated failure mode. S-II program schedule slippage has been projected at four to five months.

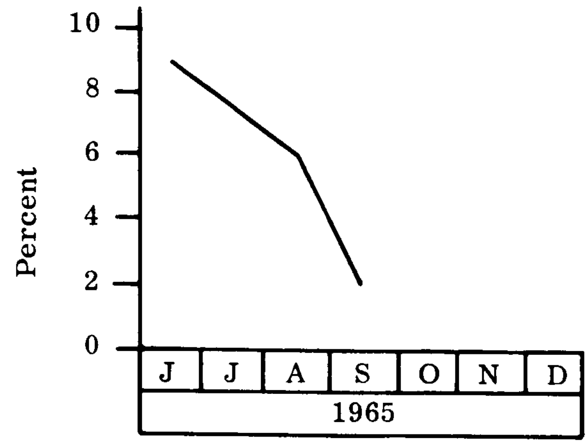


Figure 2-20. Percent of F-1 Parts Discrepant at Final Assembly

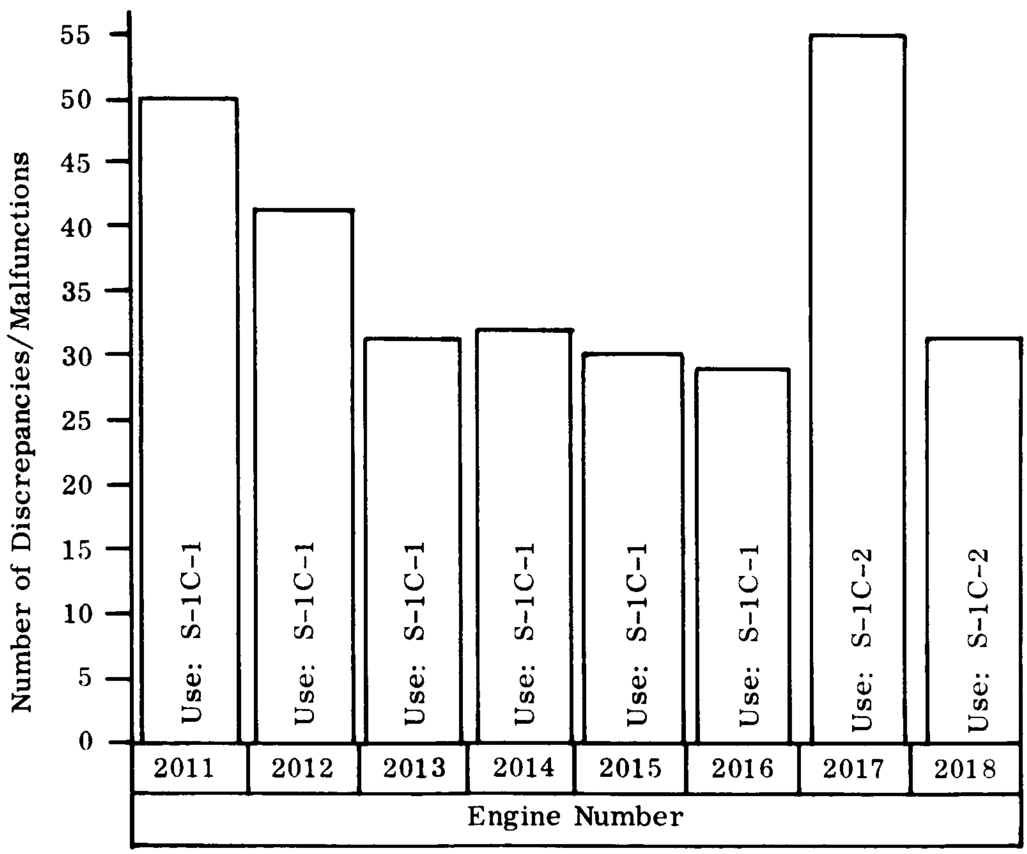


Figure 2-21. Discrepancies/Malfunctions at F-1 Electrical and Mechanical Inspection

2.3.1.1 Milestones

No information available.

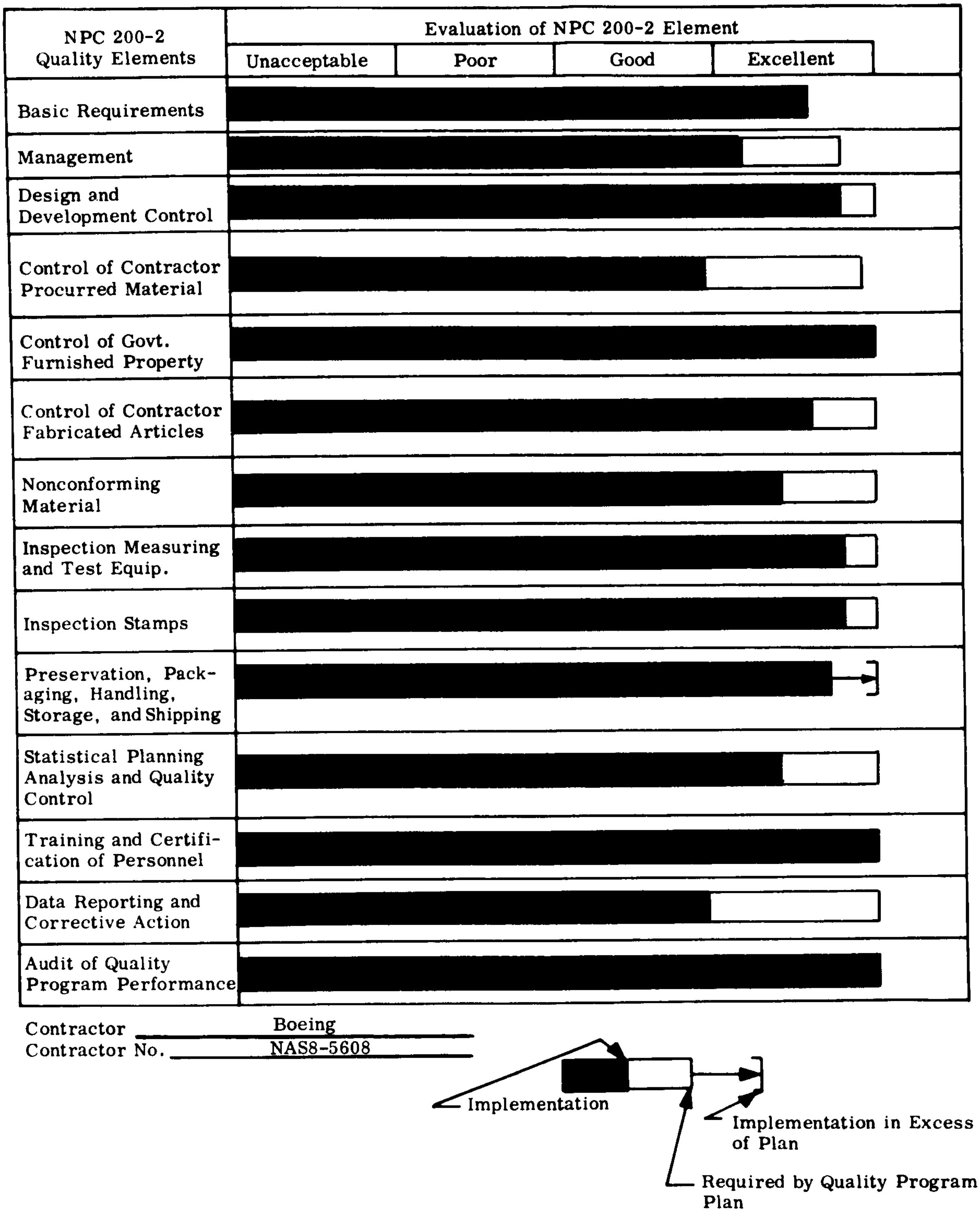


Figure 2-22. S-IC Stage Quality Assurance Evaluation Based on NPC 200-2

2.3.1.2 Reliability Program

Status of the reliability program as of 1 October 1965 is shown in Figure 2-23. Comparison with the last report shows that progress has been made in nearly all areas and that approximately 96 percent of the contract requirements have been implemented.

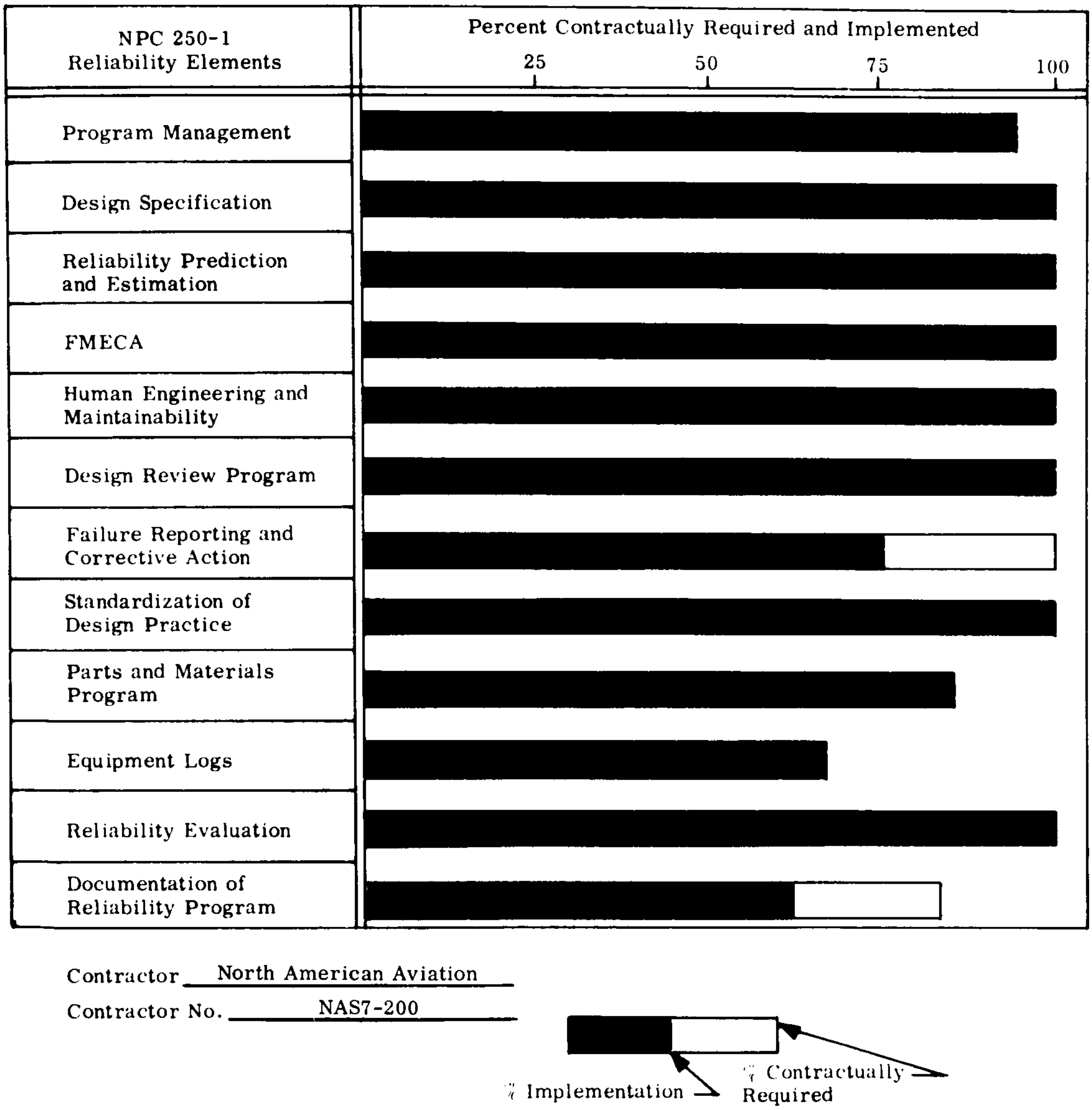


Figure 2-23. S-II Stage Reliability Assurance Evaluation Based on NPC 250-1

2.3.2 RELIABILITY ENGINEERING

2.3.2.1 Design

The insulation bonding problem, previously reported, is still the major concern. Continued separation of the bonding suggests this basic design approach should be reviewed.

2.3.2.2 FMECA

The ten most critical items list (Figure 2-24) was prepared from advance information which is expected to appear in the next revision of "Saturn V Reliability Analysis Model SA-501," R-P&VE-VOA-65-64.

Item	Subsystem	Criticality Ranking by Flight Stage			
		S-II-501			
Module, Electrical Sequence Controller	Electrical Control System	1			
Connectors, Electrical Sequence Controller	Main DC Power Distribution/Electrical Power System	2			
Connectors	Not Determined	3			
Switch Selector Assembly	Electrical System	4			
Connectors	Main DC Power Distribution/Electrical Power System	5			
Static Power Inverters	Recirculation and Ignition Power Distribution/Electrical Power System	6			
Prevalve Control Circuit	Not Determined	7			
EBW Detonators (First Plane Separation)	Separation System	8			
EBW Detonators (Second Plane Separation)	Separation System	9			
EBW Detonators (Ullage Motor)	Separation System	10			

Items Dropped from Preceding List:

Rank	Item

Figure 2-24. S-II Stage Ten Most Critical Items

2.3.2.3 Mathematical Model

No information has become available since the last report.

2.3.2.4 Apportionment and Prediction

Predictions for the S-II stage shown in Figure 2-25 were obtained from the Saturn V program office.

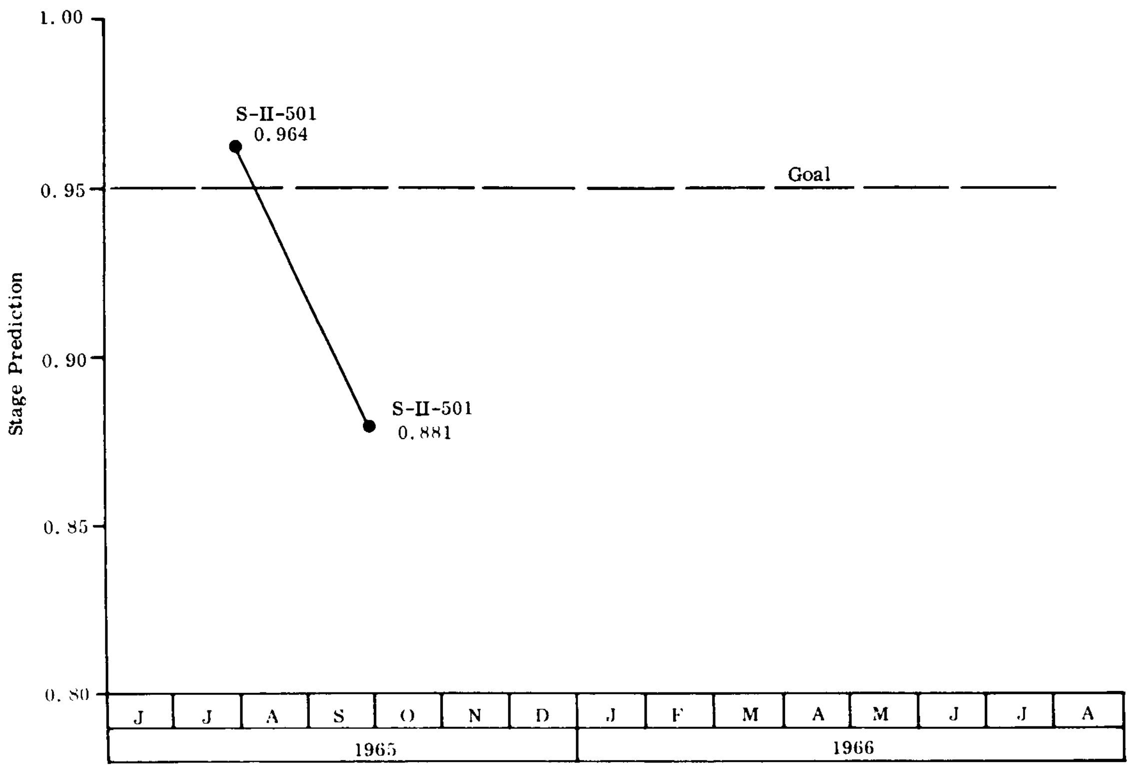


Figure 2-25. S-II Stage Reliability Trend (Mission Success)

2.3.3 TEST PROGRAM

2.3.3.1 Ground Support Test

LH_2 loading has been conducted, and the common bulkhead withstood cryogenic shock in good shape.

Complete failure occurred during the dynamic testing of the S-II-S. The failure mode was unexpected and very difficult to define. There presently appears to be a four-to-five-month schedule slippage which makes the S-II the most critical stage of the Saturn V launch vehicles.

2.3.3.2 Qualification Test

The current status of the S-II component qualification testing is shown in Figure 2-26. As of 1 November 1965, 58 percent of the items to be qualified were behind schedule. This is an increase of nine percent since the last report period.

2.3.4 QUALITY ASSURANCE

2.3.4.1 Quality Trends

No current information available.

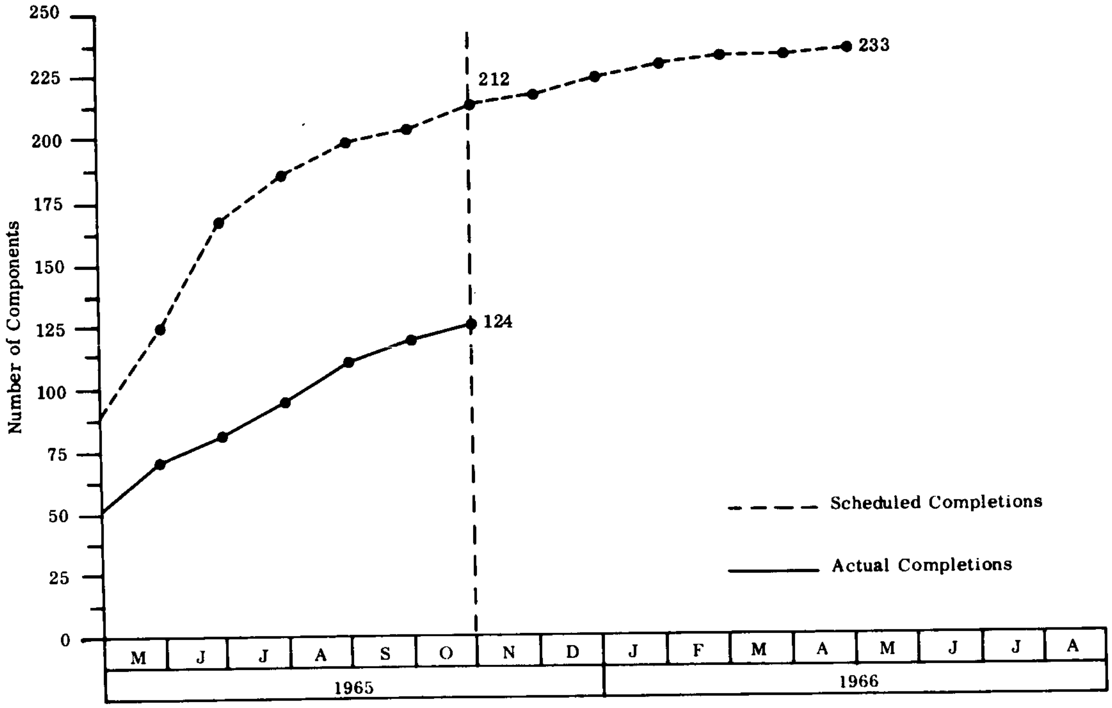


Figure 2-26. S-II-501 Stage Total Component Qualification

2.3.4.2 Quality Problems

During LOX bulkhead pressure test on S-II-1, a crack appeared in the dollar weld in the general area of numerous weld repairs. This problem will probably result in an additional four-to-six-week delay.

2.3.4.3 Quality Program

Figure 2-27 shows the status of the S-II quality program as of September 1965 based on NPC 200-2.

2.4 S-IVB STAGE

2.4.1 GENERAL

Reliability and quality activity pertinent to the 200 series S-IVB vehicles is reported in Section 1. This section of the report is devoted to reliability and quality assurance activity on the 500 series S-IVB vehicles (S-IVB/V). Status reported here should be viewed as an extension of that activity reported in Section 1.

The S-IVB-501 is scheduled for delivery to KSC on 31 July 1966. The first Douglas assessment for the S-IVB/V is scheduled for the first quarter of 1966.

2.4.1.1 Milestones

Reliability and quality assurance milestones for the S-IVB program are keyed to stage delivery dates (see Figure 2-28).

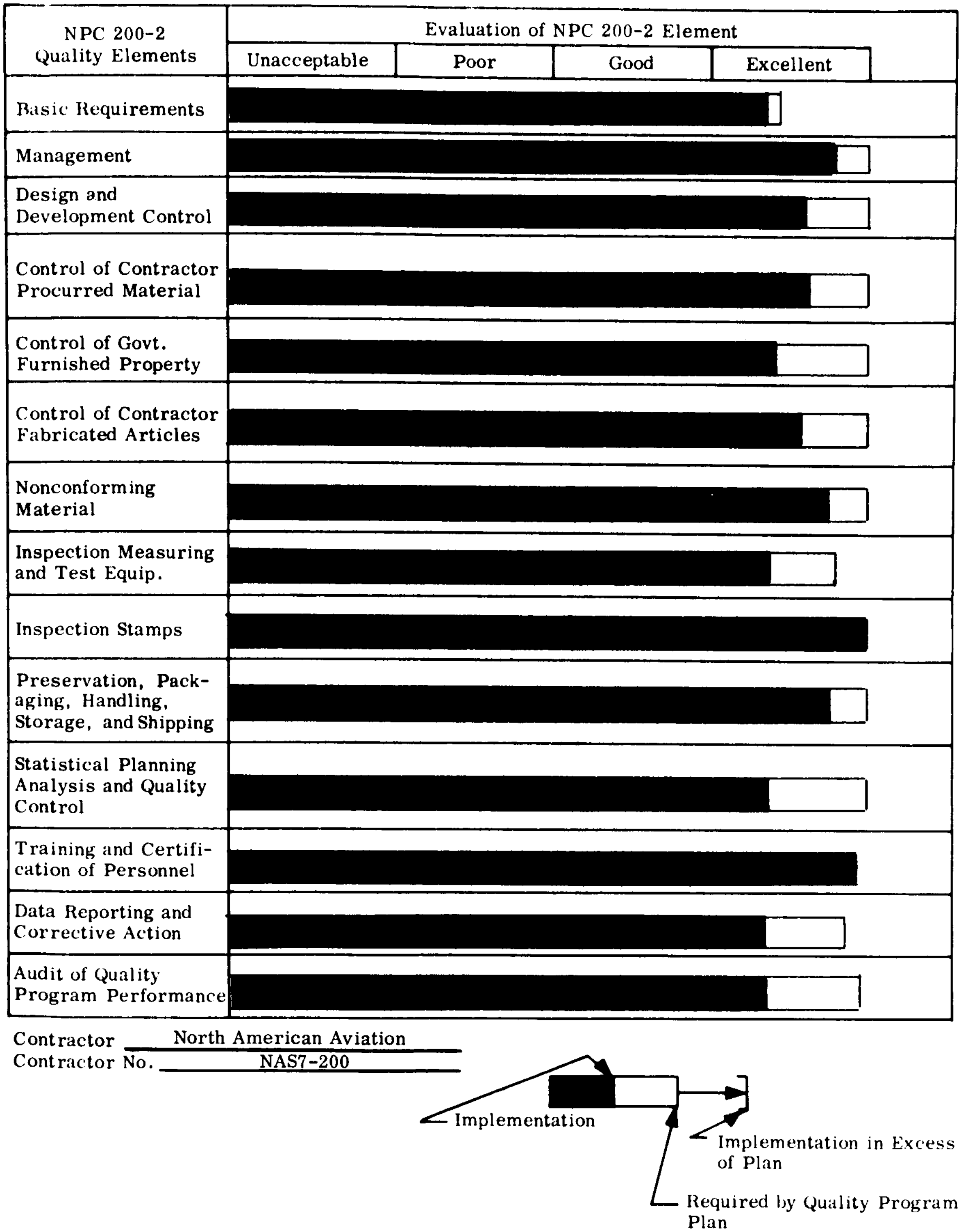


Figure 2-27. S-II Stage Quality Assurance Evaluation Based on NPC 200-2

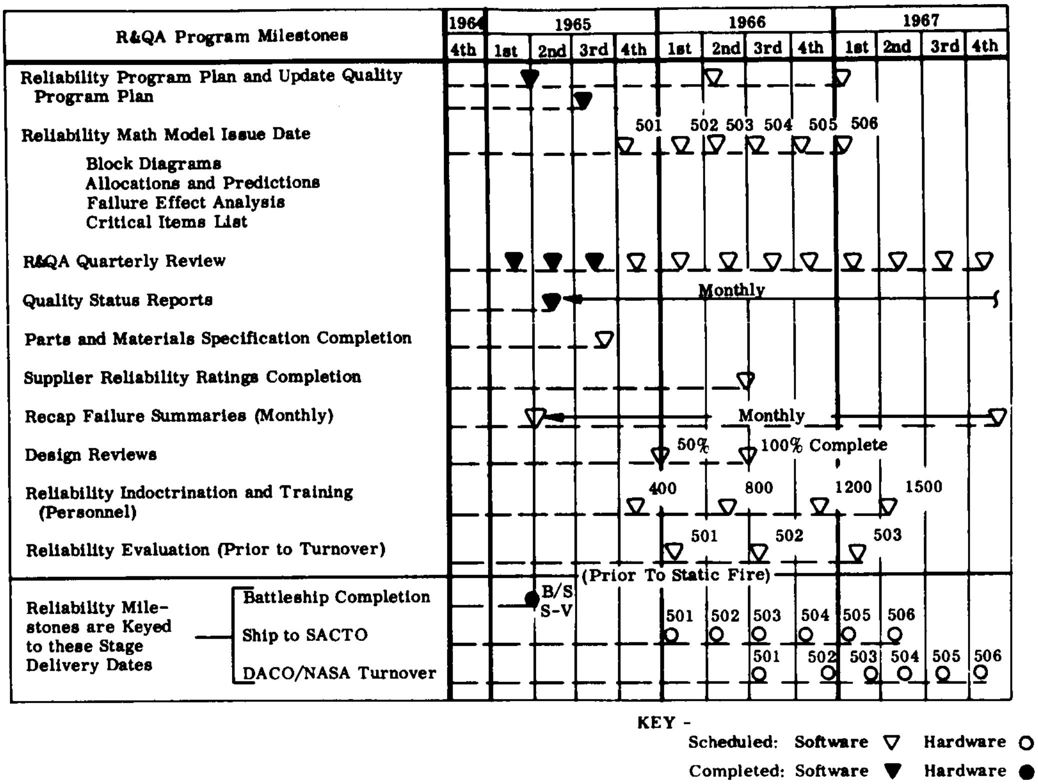


Figure 2-28. Saturn V S-IVB Stage Reliability and Quality Assurance Milestones

Significant accomplishments during this period include:

a. Completion of S-IVB factory checkout.

b. Jamb ring-weld repair for LOX tank and LH_2 tank was performed and the fix was successfully tested (S-IVB-501).

2.4.1.2 Reliability Program

Reliability program survey results are presented in Section 1, Figures 1-21 and 1-22.

2.4.2 RELIABILITY ENGINEERING

2.4.2.1 Design

Fuel System - A new configuration of the main vent system relief valve will be used for S-IVB-202 and qualification tests. One of the previous valves, reworked to assure reliability, is installed on the S-IVB-201. New configurations will be used on S-IVB-205 and S-IVB-501 and on subsequent stages of each.

2.4.2.2 Reliability Model

The reliability engineering model for the S-IVB-501 is scheduled to be issued during the fourth quarter 1965.

The critical items list for the S-IVB-501 in the "Saturn V Reliability Analysis Model SA-501" (R-P&VE-VOA-65-64), 7 September 1965, has been updated, and the current rankings are shown in Figure 2-29.

Item	Subsystem	Criticality Ranking by Flight Stage			
		S-IVB-501			
Hydraulic System Ducting	Hydraulic Power Supply	1			
Oxidizer Prepressurization	Oxidizer Pressurization	2			
Fuel Tank Vent System Tubing	Fuel Tank Pressurization	3			
Hydraulic Pump Electic Motor	Hydraulic Power Supply	4			
Helium Dump Valve	Attitude Control	5			
Fuel Tank Vent and Relief Valve	Fuel Tank Pressure Relief and Vent Control	6			
Helium Supply Shut-off Valve	Oxidizer Pressurization	7			
Oxidizer Pressurization Relief Valve	Oxidizer Pressurization	8			
Pressure Relief Valve	Attitude Control	9			
LOX Tank Vent and Relief	LOX Tank Pressure Relief and Vent Control	10			

Items Dropped from Preceding List:

Rank	Item

Figure 2-29. Saturn V S-IVB Stage Ten Most Critical Items

2.4.2.3 Apportionments and Predictions

The predictions shown in Figure 2-30 were obtained from the MSFC Saturn V program office and are current through 1 October 1965.

2.4.2.4 Reviews, Certifications, and Assessments

Program checkpoints for the Saturn V program are listed as follows:

- Quarterly Project Review (QPR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Certificate of Flight Worthiness (COFW)
- First Article Configuration Inspection (FACI)
- Design Certification Review (DCR)
- Launch Vehicle Preliminary Flight Readiness (LVPFR)
- Flight Readiness Review (FRR)

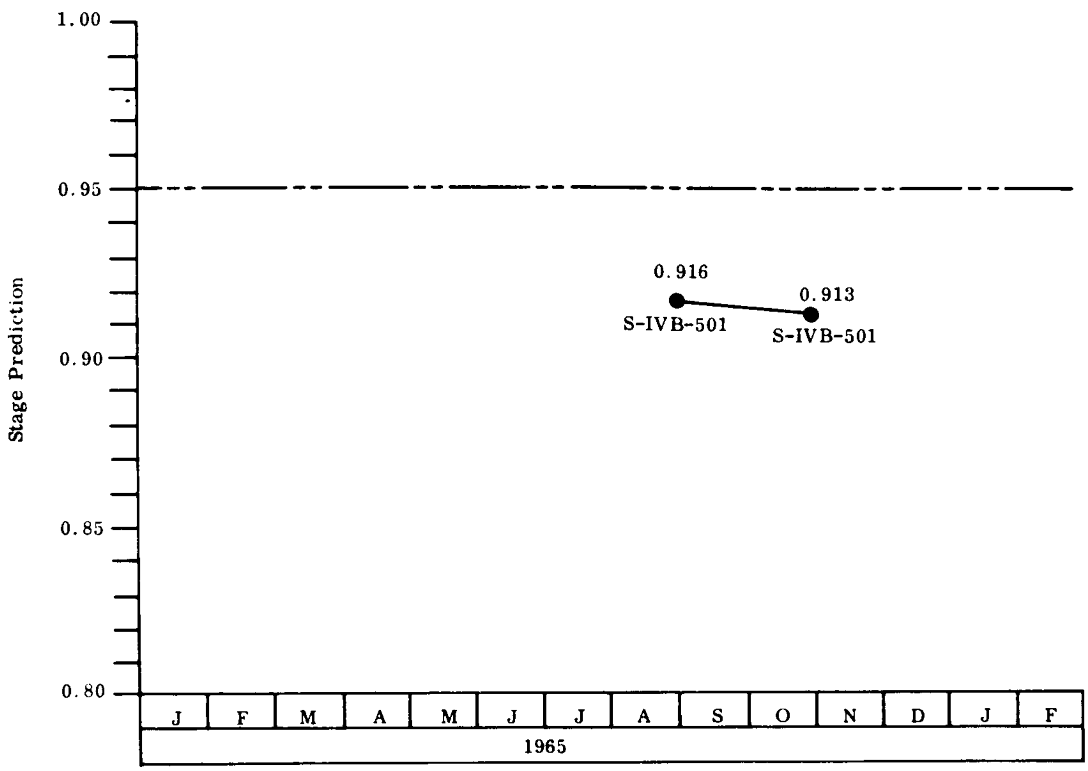


Figure 2-30. Saturn V S-IVB Stage Reliability Trend (Mission Success)

Review, certification, and assessment requirements for the S-IVB/V stages 501, 502, and 503 are presented in Figure 2-31.

		PRR	PDR	CDR	COFW	FACI	DCR	LVPFR	FRR
S-IVB-501	Required	X	X	X	X	Partial Configur-ation Audit	N/A	X	X
	Completed								
S-IVB-502	Required	X	N/A	N/A	X	Partial Configur-ation Audit	N/A	X	X
	Completed								
S-IVB-503	Required	X	N/A	N/A	X	X	X	X	X
	Completed								

Figure 2-31. Saturn V S-IVB Stage Program Checkpoints

2.4.3 TEST PROGRAM

2.4.3.1 Ground Support Test

The Saturn S-IVB Battleship at MSFC was fired for 400 seconds on 15 September 1965.

2.4.3.2 Qualification Tests

As of 19 October 1965, qualification of S-IVB/V components was 56 percent behind schedule. See Figure 2-32. The qualification test program for the S-IVB-501 is scheduled to be completed in June 1965.

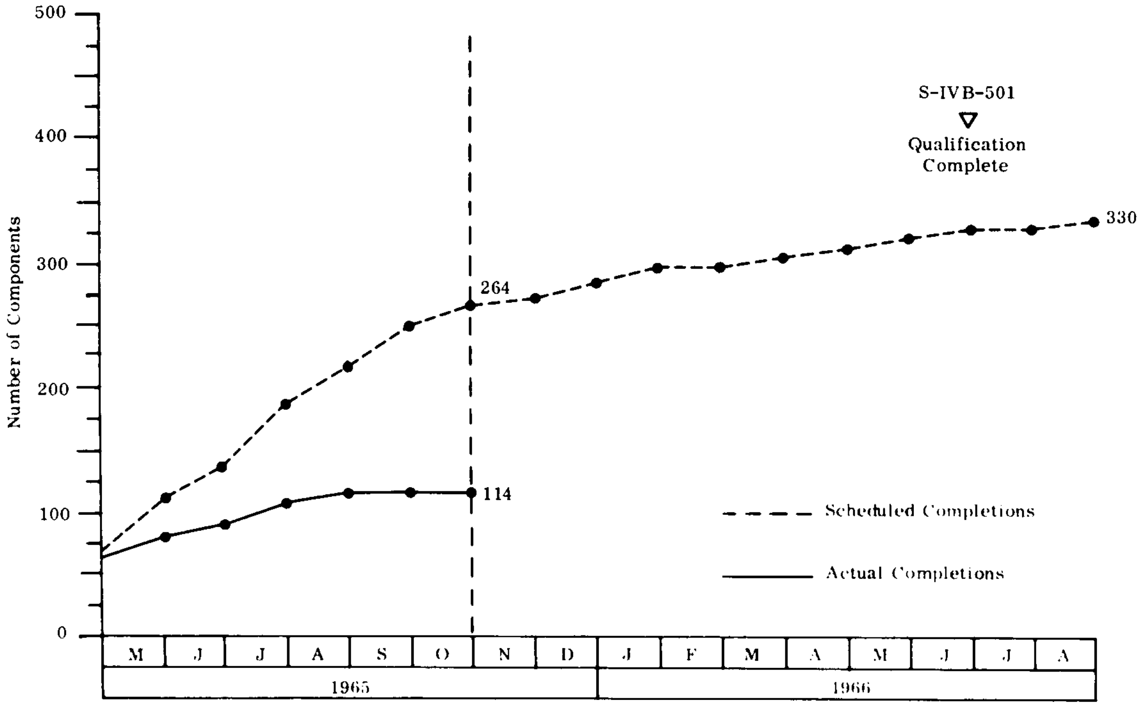


Figure 2-32. S-IVB-501 Stage Total Component Qualification

2.4.4 QUALITY ASSURANCE

2.4.4.1 Quality Trends

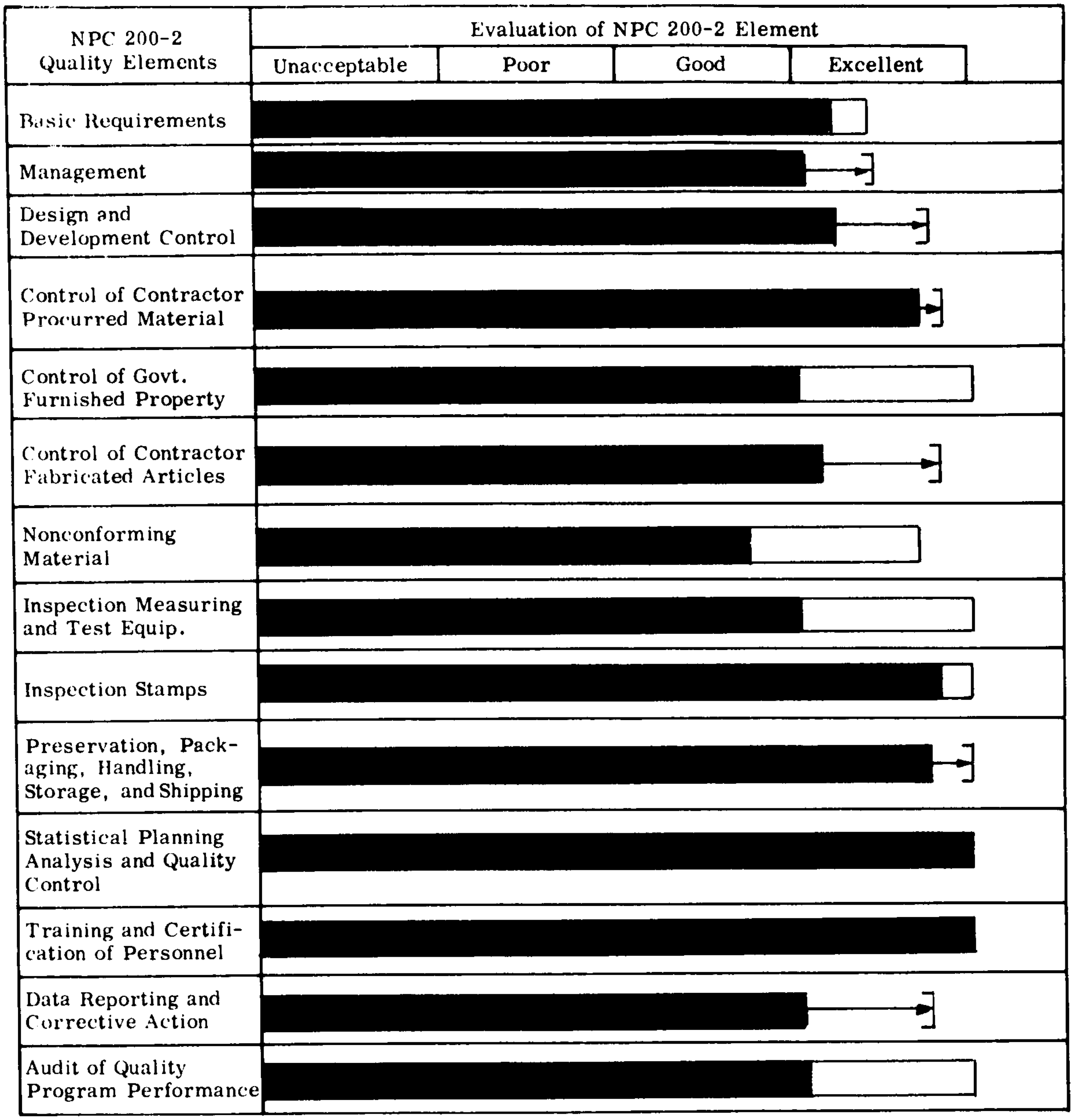
See Section 1.

2.4.4.2 Quality Problems

See Section 1.

2.4.4.3 Quality Program

Figure 2-33 shows the status of the S-IVB quality program as of September 1965, based on NPC 200-2.



Contractor Douglas
Contractor No. NAS7-101

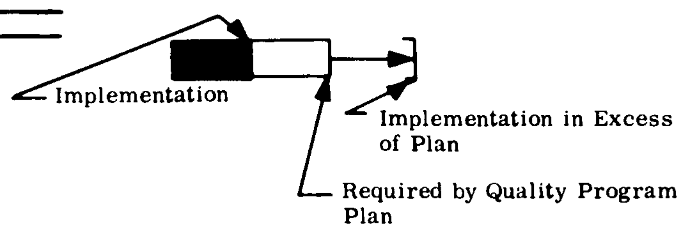


Figure 2-33. Saturn V S-IVB Stage Quality Assurance Evaluation Based on NPC 200-2.

2.5 S-IU STAGE

2.5.1 GENERAL

2.5.1.1 Milestones

Figure 2-34 shows the documentation milestones used as a basis for the Saturn IB/V Instrument Unit reliability and quality status against the Saturn V delivery schedule.

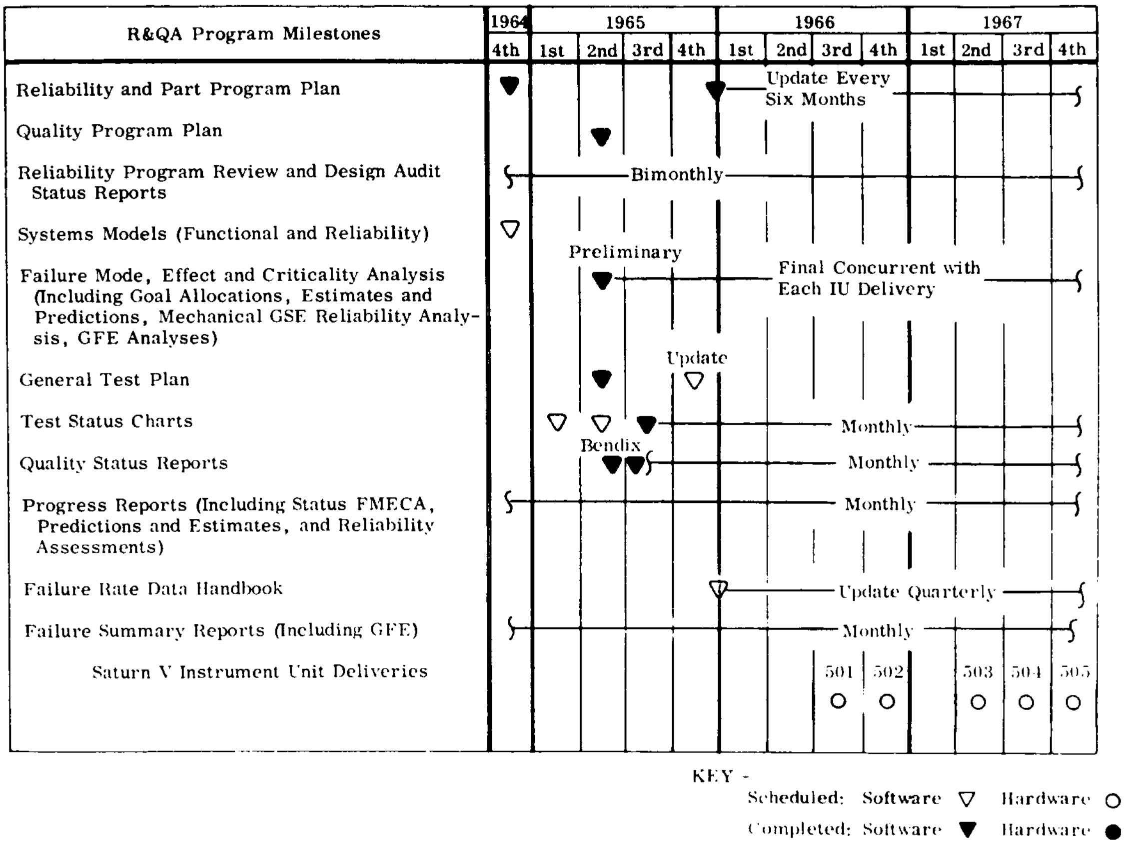


Figure 2-34. Saturn V Instrument Unit Reliability and Quality Assurance Milestones

2.5.1.2 Reliability Program

This section of the report covers the reliability and quality assurance activities for the 500-series IU stages. Status reported here should be viewed as an extension of the 200-series status reported in Section 1.

2.5.2 RELIABILITY ENGINEERING

The ten most critical items for S-IU-501 shown in Figure 2-35 are the same as those shown in the third quarter R&QA status report. Action to reduce the criticality of some of these items has been identified as follows:

- Inertial Platform - Redundancy provided by the spacecraft guidance package during the S-IVB ignition has been proposed effective with the AS-207 mission.
- Battery D-10 - Redundancy has been proposed by IBM, approval is pending. Figure 2-36 shows the reliability trend, based on predictions, for the Saturn V Instrument Unit.

Status of the Saturn IB/V Instrument Unit reliability program in relationship to NPC 250-1 is presented in Section 1.

Item	Subsystem	Critical Ranking by Flight Stage			
		S-IU 501			
Inertial Platform	Guidance	1			
Thermal Conditioning	Environmental Control	2			
Battery (D-10)	Electrical	3			
Battery (D-20)	Electrical	4			
Platform Electronics Assembly	Guidance	5			
Launch Vehicle Digital Computer	Guidance	6			
Gas Bearing Supply	Environmental Control	7			
Electrical Distribution	Electrical	8			
Launch Vehicle Data Adapter	Guidance	9			
Platform AC Power	Guidance	10			

Items Dropped from Preceding List:

Rank	Item

Figure 2-35. Saturn V Instrument Unit Ten Most Critical Items

2.5.3 TEST PROGRAM

S-IU-501 component qualification test status is shown in Figure 2-37. As of 30 September 1965, thirty percent of the items to be qualified were behind schedule.

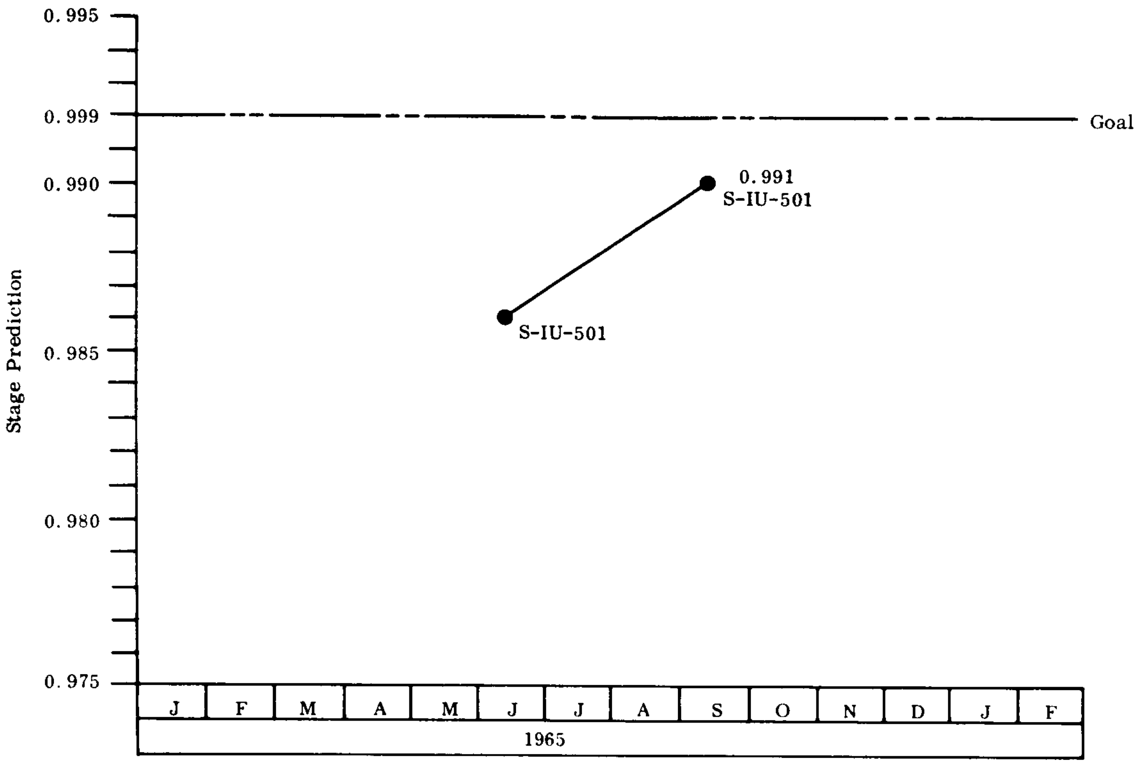


Figure 2-36. Saturn V Instrument Unit Reliability Trend (Mission Success)

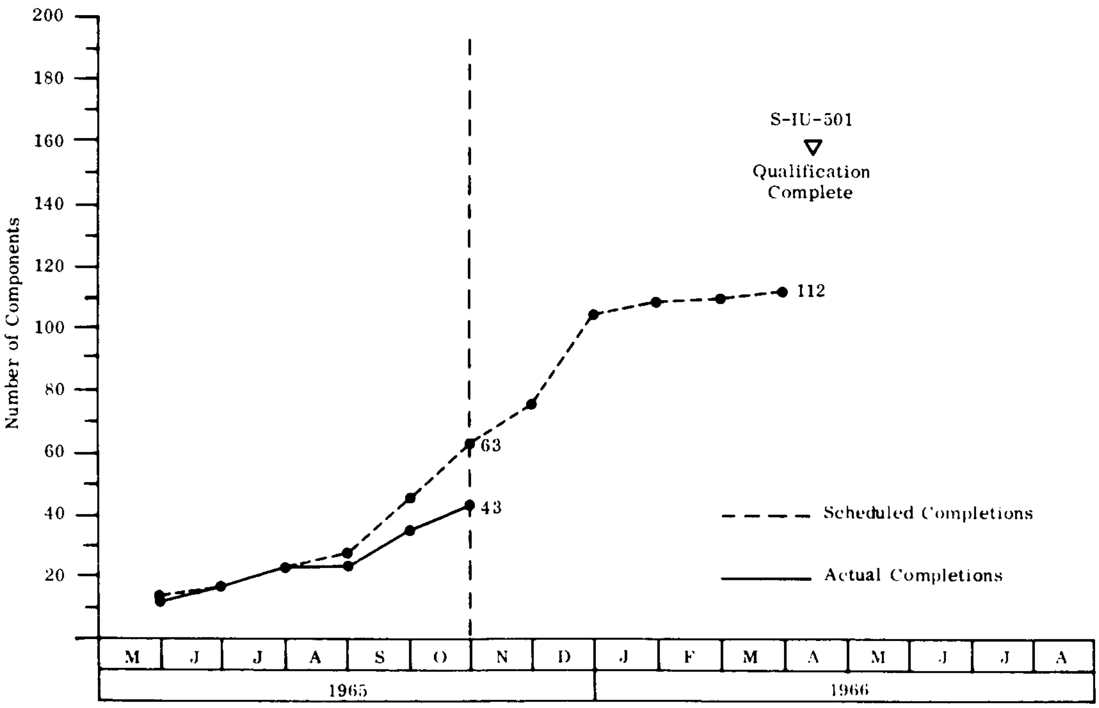


Figure 2-37. S-IU-501 Stage Total Component Qualification

The S-IU-501 checkout facility at IBM is being paced by ESE. The expected ESE delivery date has slipped from 1 December 1965, to 15 March 1966. However, no impact on S-IU-501 delivery to KSC is predicted at this time.

2.5.4 QUALITY ASSURANCE

2.5.4.1 Quality Trends

No current information available.

2.5.4.2 Quality Problems

No current information available.

2.5.4.3 Quality Program

Figures 2-38 to 2-40 show the status of the Saturn IB/V Instrument Unit quality program as of September 1965, based on NPC 200-2.

2.6 COMMAND SERVICE MODULE

2.6.1 GENERAL

Mission definitions for spacecrafts 017 and 020 were released during this reporting period and will be used for planning reliability support to these end items.

A schedule of reliability milestones applicable to spacecraft assigned to the Apollo-Saturn 501 through 504 missions is presented in Figure 2-41.

2.6.2 RELIABILITY ENGINEERING

For reporting and documentation consistency, the CSM contractor is attempting to standardize the number and nomenclature of subsystems associated with CSM. Presently nineteen subsystems require FMEA documentation, seventeen subsystems have been apportioned and are being modeled, while only eleven require failure reporting.

2.6.2.1 Failure Mode and Effect Analysis

The configuration of spacecraft 101 assigned to the Apollo-Saturn 207 mission will be used to prepare the basic FMEA for all Block II spacecraft.

No new information has become available to modify the originally scheduled April 1966 date for issuance of updated Block II FMEA's.

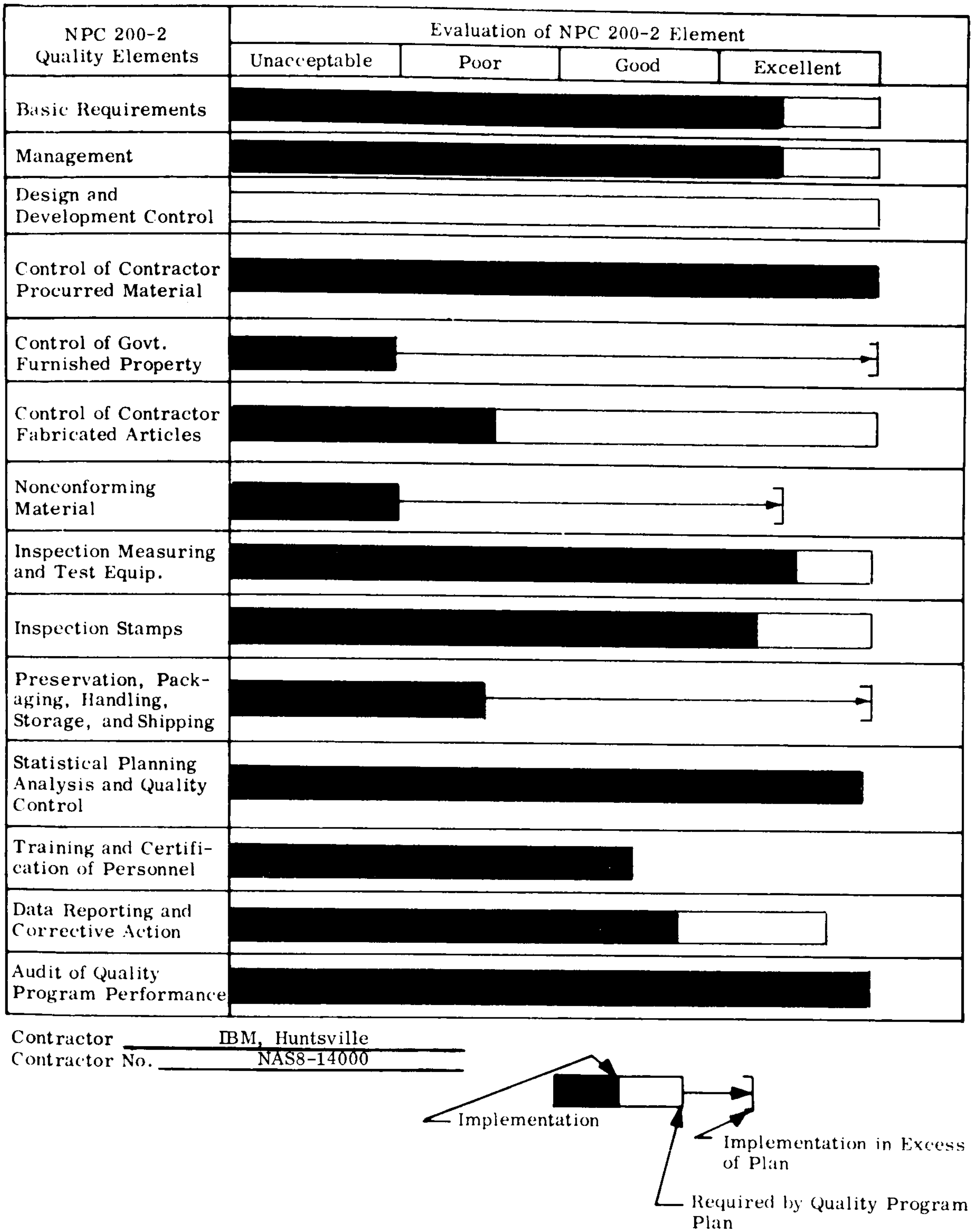
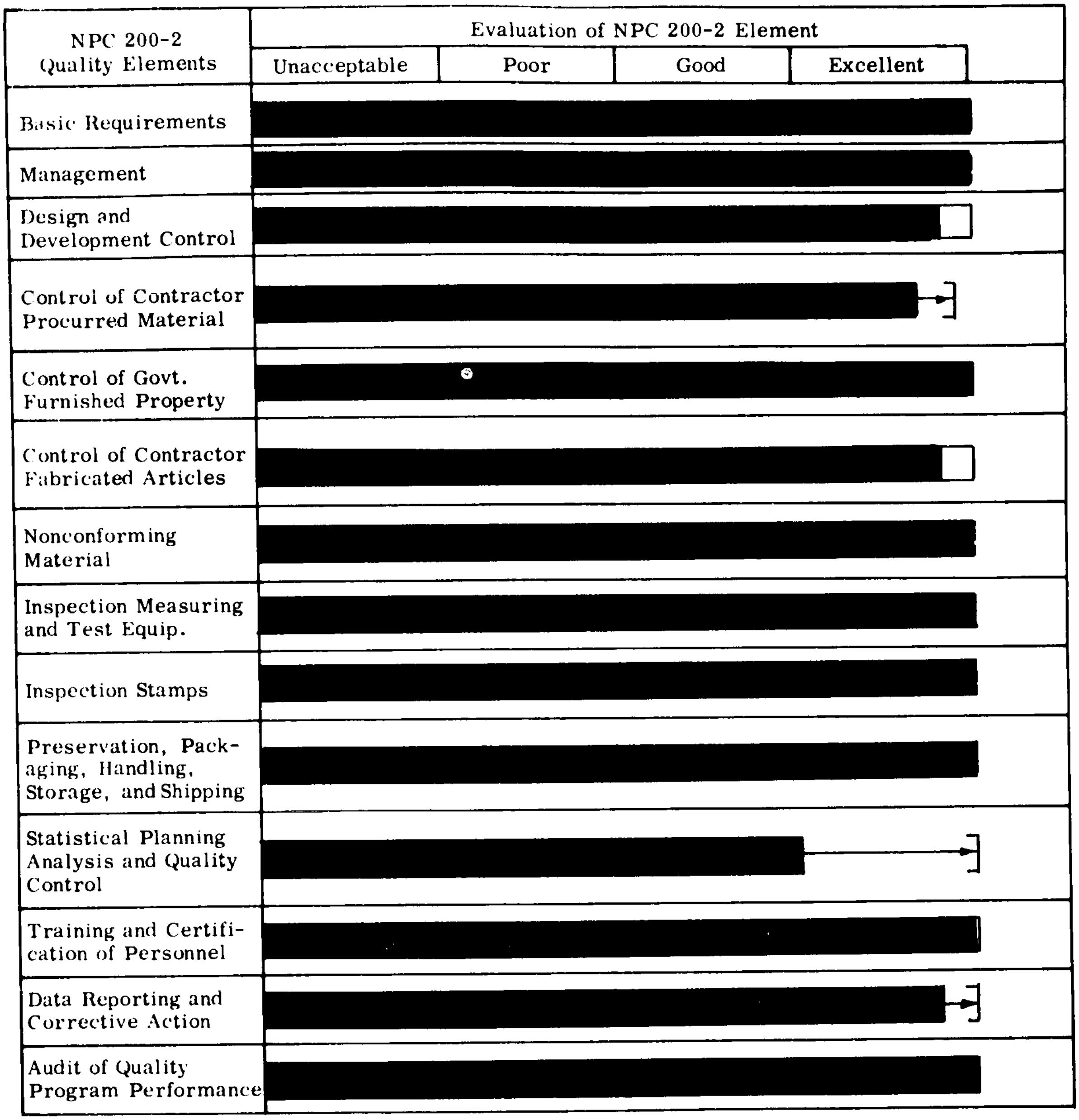


Figure 2-38. Saturn IB/V Instrument Unit Quality Assurance Evaluation, Based on NPC 200-2



Contractor IBM, Owego
Contractor No. NAS8-11561, 11562

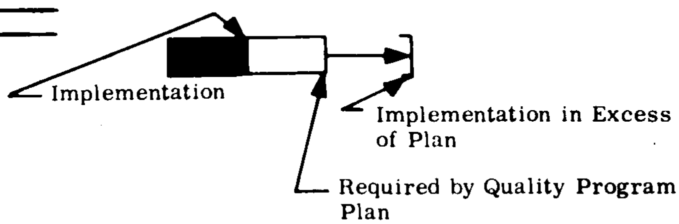


Figure 2-39. Saturn IB/V Instrument Unit Quality Assurance Evaluation, Based on NPC 200-2

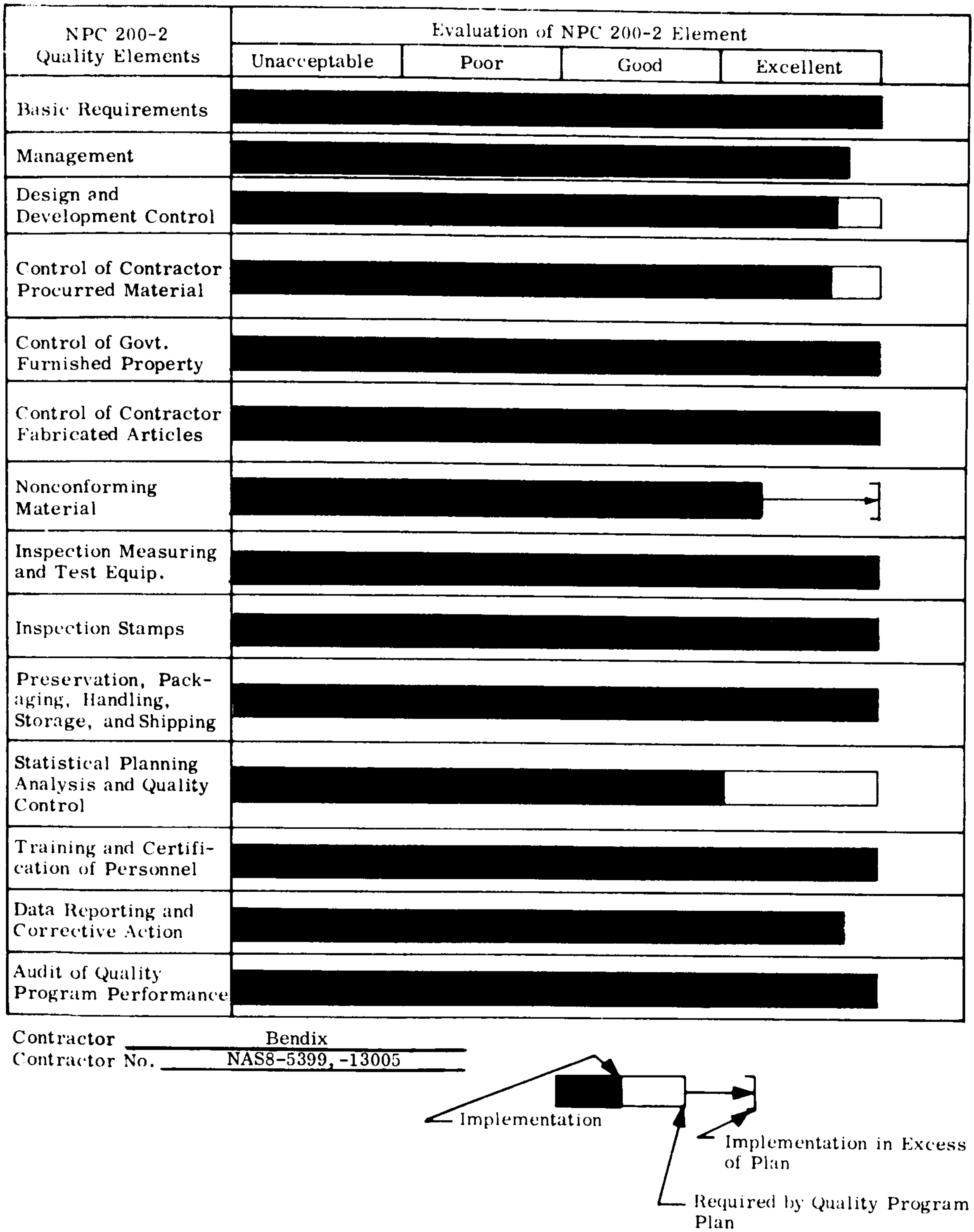


Figure 2-40. Saturn IB/V Instrument Unit Quality Assurance Evaluation, Based on NPC 200-2

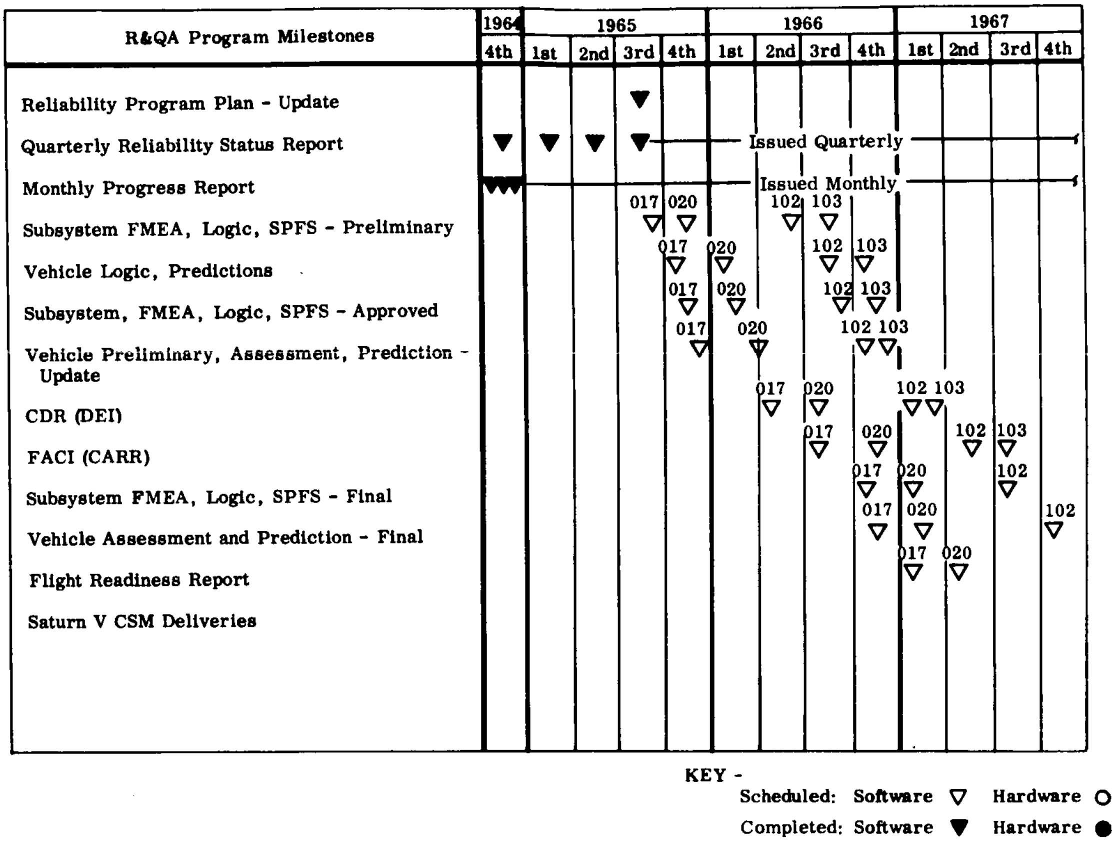


Figure 2-41. Saturn V Command Service Module Reliability and Quality Assurance Milestones

The following preliminary FMEA's have been completed for spacecraft 017 assigned to the Apollo-Saturn 501 mission:

a. Launch Escape Subsystem
b. Command Module Reaction Control Subsystem
c. Service Module Reaction Control Subsystem
d. Service Propulsion Subsystem
e. Mechanical Subsystem
f. Environmental Control Subsystem
g. Earth Recovery
h. Command and Service Module Structures
i. Waste Management
j. Crew Equipment
k. Cryogenics and Fuel Storage
l. Pyrotechnic Devices
m. Sequential Events and Control and Launch Vehicle Emergency Detection (Updated)
n. Guidance, Navigation, Stabilization, and Control
o. Caution and Warning
p. Displays and Controls
q. Electrical Power
r. Communications
s. Instrumentation.

2.6.2.2 Apportionment and Prediction

Contractor apportionments and predictions for Block II CSM mission success and crew safety are presented below:

	Reliability Goal	Reliability Prediction
Mission Success	0.9638	0.9440
Crew Safety	0.9995	0.9969

These were based upon the early definition of mission success (two-hour lunar stay instead of 34.7-hour stay through rendezvous and docking). Specification change notices have been released to revise the apportionments and predictions based on the new criteria for mission success. The notices also specified that the MSFN shall provide primary navigation in lunar orbit to reduce equipment operational duty cycles.

2.7 LUNAR EXCURSION MODULE

2.7.1 GENERAL

Contractor reliability estimates for the manned lunar landing mission have been reported as follows:

		Reliability Estimate	
	Reliability Goal	This Quarter	Last Quarter
Mission Success	0.984	0.856	0.866
Crew Safety	0.9995	0.99642	0.99680

The difference in the mission success estimate since the last reporting period can be attributed to slight decreases in the reliability estimates pertinent to the navigation and guidance and stabilization and control, descent propulsion, ascent propulsion, and environmental control subsystems.

Contractor reliability numbers presented in this section are current as of November 1965. Such current information was not available during the time the mission reliability analysis (paragraph 2.1.3 of this report) was developed. For this reason, certain differences in reliability numbers and the conclusions drawn therefrom may be observed between paragraphs 2.1.3 and 2.7 of this report.

LEM Test Articles (LTA) 10 and 2, after suitable refurbishment, are now considered the flight articles for the Apollo-Saturn 501 and 502 missions.

The Super Weight Improvement Program (SWIP) initiated by the contractor during the last reporting period continues to be fruitful in attaining significant weight reductions on the LEM. The 1 November 1965 LEM mass property control report shows a reduction of 113 pounds since the 1 October report.

An ascent engine exploded on 1 September 1965, while under test in the altitude facility at Arnold Engineering Development Center (AEDC). The HA-4 rig and test cell were also damaged. The exact cause of the explosion is still under investigation.

A reliability audit of Grumman Aircraft Engineering Corporation (GAEC) was conducted by MSC in September 1965. The formal audit report listed several areas where program improvement was indicated. These areas have been thoroughly discussed at monthly reliability status review meetings and show improvement in contractor performance.

2.7.2 RELIABILITY ENGINEERING

2.7.2.1 Design

As noted during the last reporting period, the reaction control system propellant tank reliability was affected significantly by problems encountered in development of propellant tank bladders. Bell Aerosystems has introduced an undersize bladder design which appears to have solved the bladder cycling problem. Additional feasibility testing is being conducted.

Contractor activities are continuing with regard to incorporation of failure detection devices for the reaction control system.

The apparent incompatibility of N_2O_4 oxidizer with the titanium allow reaction control tanks is the subject of concerted effort by MSC and all concerned spacecraft contractors.

During this reporting period, eight studies requiring system-level analysis were completed. These are as follows:

a. Early pressurization of ascent propulsion subsystem
b. Reliability implications due to proposed ascent trajectory changes (DRM II)
c. Degradation of S-band steerable antenna assembly performance due to lunar touchdown environments.
d. Timing electronic assembly weight - reliability trade-off study
e. Reliability effects of radiation damage to LEM transistors
f. Caution and warning electronics assembly effects on abort criteria
g. Reliability evaluation of proposed descent propulsion subsystem configuration changes
h. Radiation effects from the radio-isotope thermal-lectric generator (RTG) on pyrotechnics.

2.7.2.2 Failure Mode and Effect Analysis

During this reporting period, two FMEA's were completed, one covering the environmental control subsystem and the other, the descent propulsion subsystem (both ambient and supercritical helium). A few problem areas which were brought to light as a result of these analyses are:

Descent Propulsion Subsystem (DPS) - The main problem area affecting the supercritical helium storage section is leakage, especially into the vacuum jacket.

This failure mode would deteriorate the vacuum insulation material, raising the heat transfer rate of the supercritical helium and possibly creating a self-generating overpressure condition with eventual helium loss overboard or a tank bursting condition.

A major problem in the supercritical fuel/helium exchanger is that helium will cause freezing of the fuel standing in the heat exchanger. The throttled fuel flow may create a drastic off-nominal mixture ratio requiring mission abort with the ascent stage. Also, catastrophic failure could be caused by ice particles flowing to the engine.

Environmental Control Subsystem (ECS) - There are certain apparent deficiencies existing in the present ECS configuration that appear to require investigation:

a. The filters associated with the GOX portion can "fail closed." Presently, there is no integral by-pass. This failure mode could cause mission abort or possibly loss of crew, if both filters in the redundant lines fail closed.
b. Rupture of tubing in the secondary water management system could result in complete loss of the ascent water supply. This potential single point failure could cause loss of crew.

It should also be pointed out that any strategic ECS subsystem tubing rupture could cause loss of crew; for example, a rupture in the high-pressure oxygen supply line would deprive the crew of life sustaining oxygen.

The contractor's reliability organization has identified these problem areas through failure mode and effect analyses and has provided recommendations to the appropriate in-house activities. Recommendations to eliminate problems such as those described above have been made in the form of suggested additional studies or specific changes to configuration, procedures, specifications, etc.

2.7.2.3 Mathematical Models

The Apollo Mission Planning Task Force (AMPTF) Design Reference Mission (DRM) I issued in November 1964 was used as a reference by the LEM contractor in all reliability studies and modeling activities to date. However, per MSC direction, prelaunch time (ten hours) is no longer considered in the reliability estimates. DRM II, now in development will provide a more up-to-date mission profile and ground rules for reliability modeling purposes and will affect reliability estimates associated with all subsystems to some degree.

Contractor mission success reliability models have been developed in detail during this reporting period for the electrical power, environmental control, explosive devices subsystems, and the descent engine. Previously developed models have been reviewed and updated where required on the navigation and guidance, stabilization and control, ascent engine, propulsion pressurization and feed, communications, instrumentation and structures subsystems. Studies are continuing on all subsystems in an effort to describe their models at lower assembly levels.

Previously developed crew safety models have been reviewed and updated. However, the detailed LEM subsystem crew safety models were not integrated into an over-all LEM system crew safety model during the current reporting period. The over-all LEM system crew safety model will be generated during a future reporting period.

Equipment operating profiles to support the LEM-1, 206A, mission analysis were completed. Reliability considerations including a systems failure effects analysis were prepared and are included in the contractor's LEM-1 Mission Capability Report, LED-540-41.

2.7.2.4 Apportionment and Prediction

Subsystem reliability estimates for mission success and crew safety are continuing to change as more detailed information in terms of logic diagrams and reliability data become available. Major changes in reliability estimates during this quarter for the navigation and guidance, ascent and descent propulsion subsystems, EPS, ECS, and explosive devices are briefly discussed below:

2.7.2.4.1 Navigation and Guidance - Stabilization and Control

Reliability logic diagrams and equipment operating times have been updated. Revised failure rate information for the MIT equipment has reduced the reliability estimates for this subsystem.

2.7.2.4.2 Propulsion

Ascent - The reliability estimate has decreased due mainly to the incorporation of the propellant leakage failure mode for the 3-way solenoid valves in the ascent engine math model.

Descent - Revised failure rates for mechanical components of the descent engine have reduced the reliability estimate of this subsystem.

To eliminate problems associated with fuel freezing in the supercritical helium system (possible catastrophic failure), incorporation of a method for firing the descent engine prior to pressurization has been evaluated. This time delay would permit fuel flow before helium flow thus reducing the probability of freezing.

The supercritical versus ambient helium pressurization configuration decision still remains unresolved.

2.7.2.4.3 Electrical Power

A more detailed model was used to generate the reliability estimates which resulted in a slight increase in mission success and an insignificant decrease in crew safety estimates.

2.7.2.4.4 Environmental Control

Reliability estimates have decreased for this subsystem. These were generated from new math models and support data based upon the latest ECS configuration.

2.7.2.4.5 Explosive Devices

Mission success and crew safety estimates have increased due to a reduction of four squibs for descent deadfacing.

2.7.3 TEST PROGRAM

The LEM certification test program has been defined by the contractor and MSC. In general, qualification test completion of subsystem hardware is oriented to 15 November 1966, and constraining ground tests are scheduled for completion six weeks prior to launch dates. Problems in meeting these criteria are continually being identified, and alternative plans formulated for specific test articles are being implemented.

"LEM Program Schedule III, Revision I," dated 12 October 1965 is presently being implemented. Changes between this schedule and LEM schedule III in effect during the last reporting period are minor, affecting specific constraint and equipment transfer dates.

A tabulation of end-item test hardware and the current objectives and status of each is presented in Figure 2-42.

2.7.3.1 <u>Ground Support Test</u>

White Sands Operation (WSO) test stand 401 activation was completed 26 September 1965. Six cold-flow tests were completed on the PD-1 rig using substitute propellants. Results were considered staisfactory with all primary objectives accomplished. The Series 1 cold-flow tests with substitute propellants are now complete, and the next group of runs will be made with live propellants.

Activation of test stand 402 at WSO was accomplished on 23 September 1965. A series of cold-flow tests of the heavyweight HA-3 and the prototype PD-1 rigs with substitute propellants were completed. Four tests were conducted on HA-3. The primary objectives were to calibrate the rig and flowmeters and to determine the orifice sizes for hydraulically balancing the feed system when operating with live propellants.

2.7.3.1.1 Descent Engine

Tests on the descent engine have brought several problem areas to light. The development program at Thompson Ramo Woolridge (TRW) appears to require constant surveillance. TRW is presently modifying the throttle actuator design. This modification may not be available for LEM-1 and start of qualification tests. Other problem areas indicated to date are:

a. Injector - 50 percent performance and low stability at mid-range (40-60 percent thrust).
b. Combustion Chamber - failure of faceplate, excessive glassing in chamber, excessive erosion at throat.
c. Shutoff Valve - excessive leakage on both fuel and oxidizer sides. (Problem was evident on AEDC engine No. 2 and WSMR delivery).

End Item	Description of Objectives	Status/Comments
Test Module - 2 (TM-2)	Thermal Analysis Verification Vehicle - TM-2 is a full-scale thermal model of the LEM with a command module thermal simulator. TM-2 will be refurbished for use at White Sands Operation (WSO) in mated firing tests with LTA-5D descent stage.	Completion of ascent and mated stage thermal vacuum test is prerequisite to LTA-8 thermal vacuum testing.
TM-5	Landing Stability Test Vehicle - A specially lightened descent stage structure with production landing gear. It will be ballasted to LEM inertia with c. g. position but at 1/6 LEM weight.	May be deleted from program. Stop work order issued. Design changes have made value of this vehicle questionable. Planned drop tests may be integrated into LTA-3 test program.
ESI	House Spacecraft No. 1, Phase I - ESI is used for electronic system integration testing and is a facsimile structure with geometrically correct equipment locations. It will insure operational compatibility of electronic subsystems in a LEM-1 system configuration and LEM/ACE interfaces.	Phase I testing scheduled for first half of 1966.
LTA-1	House Spacecraft No. 1, Phase II - LEM configured vehicle used for system integration, electromagnetic compatibility, and support of LEM's.	In manufacturing, final assembly. Phase II testing scheduled for third quarter 1966.
LTA-2	LEM, launch vehicle for dynamic tests - A LEM structure consisting of a mass representation of ascent stage and a preproduction descent stage with simulated equipment. Vehicle has correct weight and c. g. for dynamic tests. Will have off load capability of 17,000 pounds for flight on Apollo-Saturn 502.	Currently undergoing vibration test at MSFC. Present plans call for refurbishment and flight on Apollo-Saturn 502.
LTA-3	LEM Structural Demonstration Vehicle. A structurally complete ascent and descent stage. It will be subjected to hydrostatic pressure, vibration, structural drop, static structural, manned drop, and falling load demonstration tests.	In manufacturing.
LTA-5D	Propulsion/Structure Compatibility Vehicle - A flight weight structure with descent propulsion subsystem and mass representation of remaining subsystem hardware. Used for mated (with refurbished TM-2) and unmated descent propulsion firings in high altitude development facility at White Sands Operation.	In manufacturing. Mated firings with inert TM-2 is a constraint on LEM-1 flight.
LTA-8	Thermal Vacuum Demonstration Vehicle - This vehicle will comprise a complete LEM-1 configuration. It will be tested at MSC to demonstrate manned and unmanned integrated systems performance under thermal vacuum conditions.	In manufacturing. Mission simulation tests required prior to Apollo-Saturn 206 flight.
LTA-10	LEM-SLA Structural Test Vehicle - a descent structure without ballast for use at NAA in static structural tests with SLA. This vehicle is to be ballasted to control weight for flight.	Undergoing test at NAA, Tulsa. Present plans call for refurbishment and flight on Apollo-Saturn 501.

Figure 2-42. LEM Test Hardware

2.7.3.1.2 Ascent Engine

Bell Aerosystems reported the first injector, utilizing a separable bipropellant cooled shower-head baffle, was fired for full duration in an ablative barrel.

They dynamic simulation of launch/boost and lunar descent has been successfully completed on an ascent engine in the x-x axis. After completion of dynamic simulation in the y-y and z-z axes, the engine will be fired for full duration.

Ascent engine start characteristics require confirmation at high altitudes in a cold environment; "hard starts" may be encountered.

An ascent engine exploded on 1 September 1965, while under test in the altitude facility at AEDC. The exact cause of the explosion is still under investigation. An ascent propellant tank failed after 47 hours of exposure to N_2O_4 (oxidizer) at Aerojet on 3 November 1965. Failure analysis is in process.

2.7.3.1.3 Reaction Control

Failures experienced on Apollo RCS tanks after oxidizer storage may have detrimental effects on LEM tank deliveries. MSC and all concerned contractors are directing concerted effort to resolve this problem.

During an acceptance test, engine performance during pulse operation was substandard. This has now occurred on two additional engines (spacecrafts 1010 and 1016). Failure analysis is in process.

A number of bladder failures have occurred during design feasibility testing. As an end result of the development program concerning these failures, Bell Aerosystems has designed an undersize bladder (1/8 inch less about the cylindrical section). Three undersized bladders have been tested with the results depicted in Figure 2-43.

Test Number	Number of Cycles	Remarks
1	20	No failure.(1) Plexiglass tank using Freon TF as a reference propellant.
2	18	Failed(2) at 18th cycle (small tear on bottom of tank assembly). Titanium tank using actual propellants.
3	20	No failure. Titanium shell with actual propellants.
	+ more tests at revised vibration levels	

Notes: (1) The requirement is 20 expulsion cycles without failure.
(2) Unrealistic vibration levels; therefore, failure was discounted and vibration levels were revised for test No. 3.

Figure 2-43. Undersize Bladder Tests

Based on the above test results, the contractor feels that the undersize bladder has successfully solved the problem of bladder displacement during expulsion.

2.7.3.2 Qualification Test

A total of 239 subsystem qualification tests are expected to be completed prior to the flight of LEM-1. Figure 2-44 shows the present distribution of required certification tests. The LEM certification test program, of which qualification testing is a part, identifies, documents, controls, and monitors the status of all tests which must be performed to certify that a particular LEM vehicle is ready for flight.

	Distribution By Flight Vehicle Supported					
	Total	LEM-1	LEM-2	LEM-3	LEM-4	LEM-5 & On
Subsystem Qual Incl 7 GFE Items	239	239				
Subsystems Higher Level	177	98	46	3	30	-
Ground Test Vehicle	252	74	75	28	75	
Flight Test Vehicle	66	-	11	12	24	19
Total (Less Qual)	495	172	132	43	129	19
Total (Qual Incl)	734	411	132	43	129	19

Figure 2-44. Certification Test Requirement Summary Distribution by Flight Article Supported

2.7.4 QUALITY ASSURANCE

2.7.4.1 Quality Trends

Figure 2-45 shows the trend in defects per 1000 manufacturing hours on the LEM at GAEC.

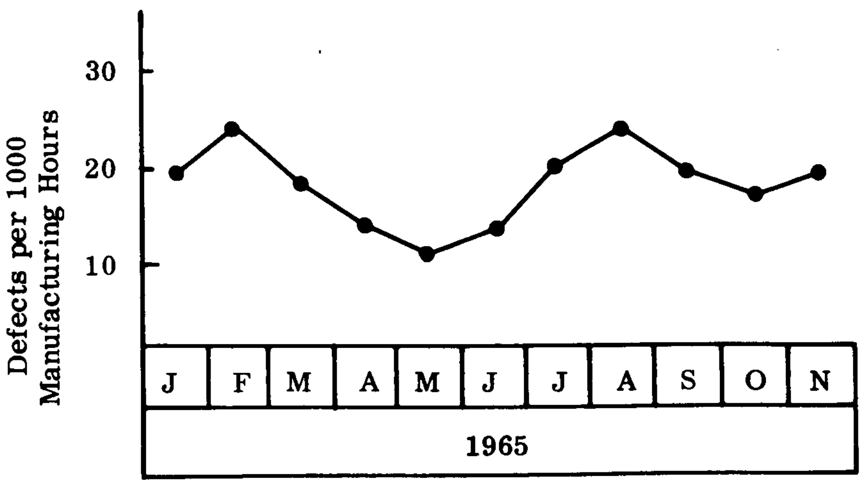


Figure 2-45. LEM Manufacturing Defects at GAEC

2.7.4.2 Quality Problems

Nothing significant to report.

2.7.4.3 Quality Program

The last Grumman Aircraft Engineering Corporation Quality Program Review (15 December) indicated major LEM subcontractor in-house quality performance as shown in Figure 2-46.

Contractor	LEM Equipment	Current Quality Performance Rating
Aerojet General	Propellant Tanks	Good (unchanged)
Allison	Descent Stage Propellant Tank Assembly	Good (unchanged)
American Bosch Arma	Caution and Warning Electronic Assembly, Signal Conditioner Electronic Assembly, and Control Assembly	Fair (unchanged)
AiResearch	Cryogenic Tanks and Gimbal Drive Actuator	Poor (down)
Bell Aerosystems	Ascent Engine	Good (improvement)
Eagle Picher	Storage Batteries	Fair (new)
Fairchild	Program Reader	Good (new)
General Electric	Electronic Ascent and Descent Control Assembly	Fair (new)
Hamilton Standard	ECS, GSE and ECS, Inverters	Fair (unchanged)
Honeywell	D'Arsonval and Cross Point Meters	Fair (improvement)
Kearfott	Rate Gyro, Helium Temp/ Pressure Indicator, Propellant Quantity Indicator	Fair (unchanged)
Lear Siegler	Attitude Indicator and Gasta	Fair (unchanged)
Link	Full Mission Simulator	Good (unchanged)
Marquardt	Reaction Control System	Good (improvement)
Radiation, Inc.	PCM Timing Equipment	Good (improvement)
Radio Corporation of America	G&N Radar, Communications, Attitude and Translation Control Assembly, PMO	Fair (unchanged)
TRW	Descent Engine, Abort Guidance System	Fair (unchanged)

Figure 2-46. Major LEM Subcontractor In-house Quality Performance

2.8 LAUNCH COMPLEX AND GSE

2.8.1 GENERAL

Crawler/Transporter No. 1, presently undergoing bearing replacement at Cape Kennedy, should be back in operation by 1 February 1966. The Mobile Service Structure (MSS) is scheduled for completion on 15 August 1966. Ground Equipment Test Sets (GETS) checks are planned for the Propellant Loading System in April 1966.

2.8.2 LAUNCH COMPLEX RELIABILITY ENGINEERING

MSFC has performed reliability assurance evaluation surveys on suppliers of MSFC-provided launch complex equipment. Three contractors, General Electric, Sanders Associates, and Boeing Company have been surveyed during this reporting period, and results are shown in Figures 2-47 to 2-49. These figures show the degree to which contractors are implementing contractually required elements of NPC 250-1.

Preliminary studies of the effects of equipment failures on launch success have been conducted on the following launch complex systems:

a. Pneumatic Converter-Compressor Facility and Distribution System
b. Saturn V Engine Deluge System
c. Holddown Arms
d. Crawler Transporter
e. Tail Service Masts
f. Service Arms
g. Service Arm Control Switch System
h. Service Arm Water Cooling System
i. Hydraulic Charging Unit
j. Liquid Oxygen System
k. Liquid Hydrogen System
l. RP-1 Fuel System
m. Environmental Control System
n. Propellant Tanking Computer System
o. Data Transmission System
p. Direct Current Power System

A brief summary of those potential failures which could result in vehicle loss or which present a safety hazard follows.

2.8.2.1 Saturn V Engine Deluge

This system contains no subsystem or component-level redundancies. Failure of the system to operate may result in vehicle loss. The system is used to aid in putting out an uncontrolled fire. In this event, a scrub would already be a certainty; however, premature operation of the deluge system could result in an abort. A review of the entire system will be made by KSC.

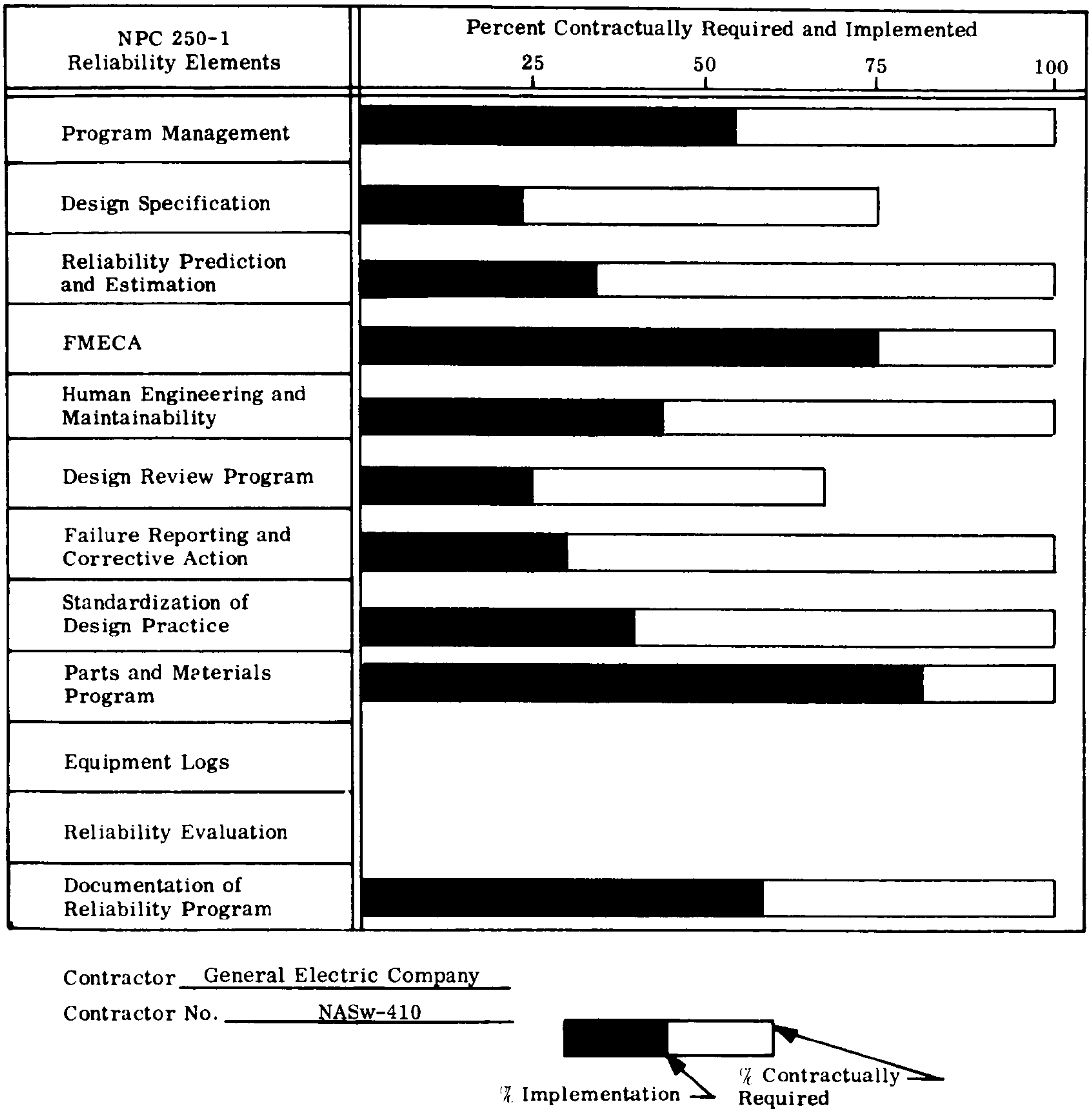
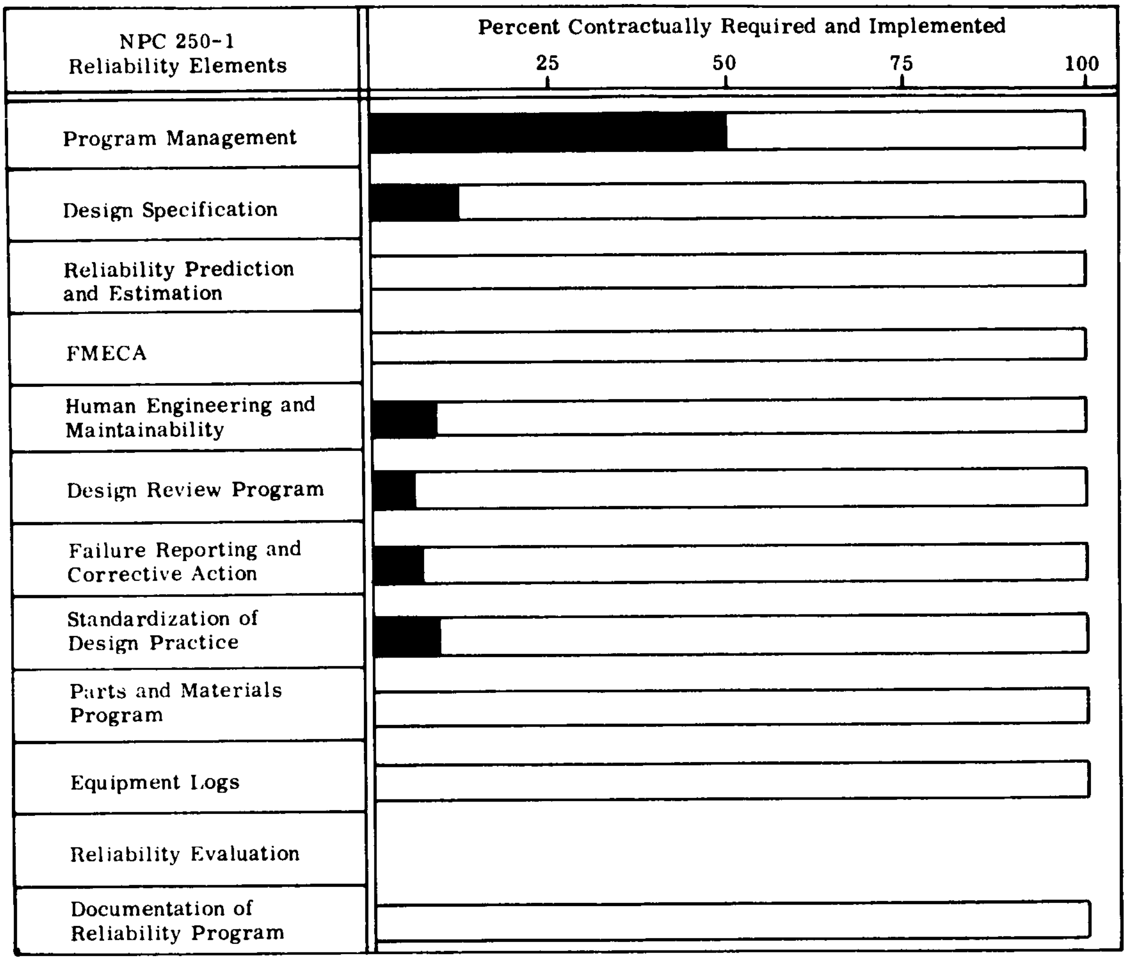


Figure 2-47. Saturn V ESE Reliability Assurance Evaluation, Based on NPC 250-1



Contractor Boeing

Contractor No. NAS8-5608

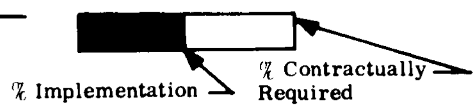
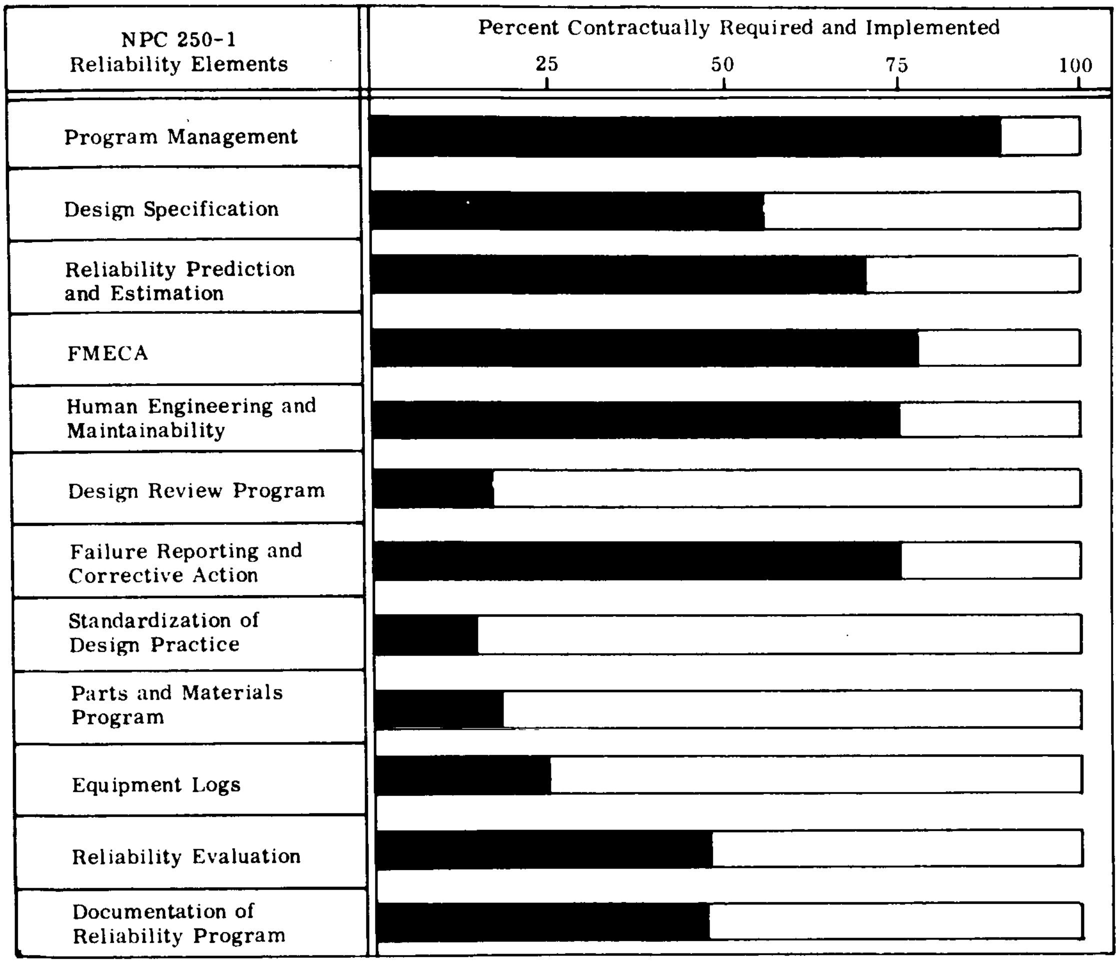


Figure 2-48. Saturn V GSE Reliability Assurance Evaluation, Based on NPC 250-1

[redacted]



Contractor Sanders Associates

Contractor No. NAS8-14009

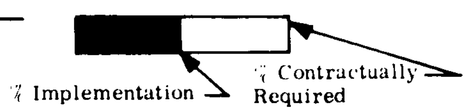


Figure 2-49. Saturn V ESE Reliability Assurance Evaluation, Based on NPC 250-1

[redacted]

2.8.2.2 Holddown Arms

The design of the holddown arms does not provide for redundancy in the release mechanism. Failure of any one or all of the arms will result in an abort or possible loss of the vehicle.

A single pressure switch and feed back circuit indicate system pressure. If this fails, no other means are available to determine pressure, thereby resulting in a hold or scrub.

2.8.2.3 Service Arms

In general, the three preflight service arms (S-IC intertank, S-IC forward and S-II aft) do not have redundancy. This includes the replenish, unlock, extend, retract, and withdrawal system functions. Failure of these functions could result in a possible mission scrub.

The command module access arm does not have redundancy. This arm retracts at about T -60 seconds, and if it fails to retract, a mission scrub could result.

The five in-flight service arms (S-II intermediate, S-II forward, S-IVB aft, S-IVB forward, and service module) all have alternate modes of operation and redundancy which permit most of the functions to be performed. Not all of the equipment, however, is backed-up. For example, the electrical control circuit which resets all pilot and command valves can cause a possible vehicle loss. This could be caused by a shorted switch or relay contact which would prevent arm retraction withdrawal. In addition, a failure in the lanyard cable secondary-disconnect mechanism could cause a loss of arm tracking ability, thereby causing umbilical disconnect. Liquid hydrogen and oxygen would be sprayed on the launch vehicle causing an extreme fire and crew safety hazard.

No corrective actions are presently planned to alleviate the inflight service arm problem areas.

2.8.3 QUALITY ASSURANCE

2.8.3.1 Quality Program

MSFC Saturn V ESE general test plan was issued in September 1965.

Figures 2-50 and 2-51 depict the status of General Electric ASD's ESE and Boeing Company's GSE quality programs as of September 1965, based on NPC 200-2.

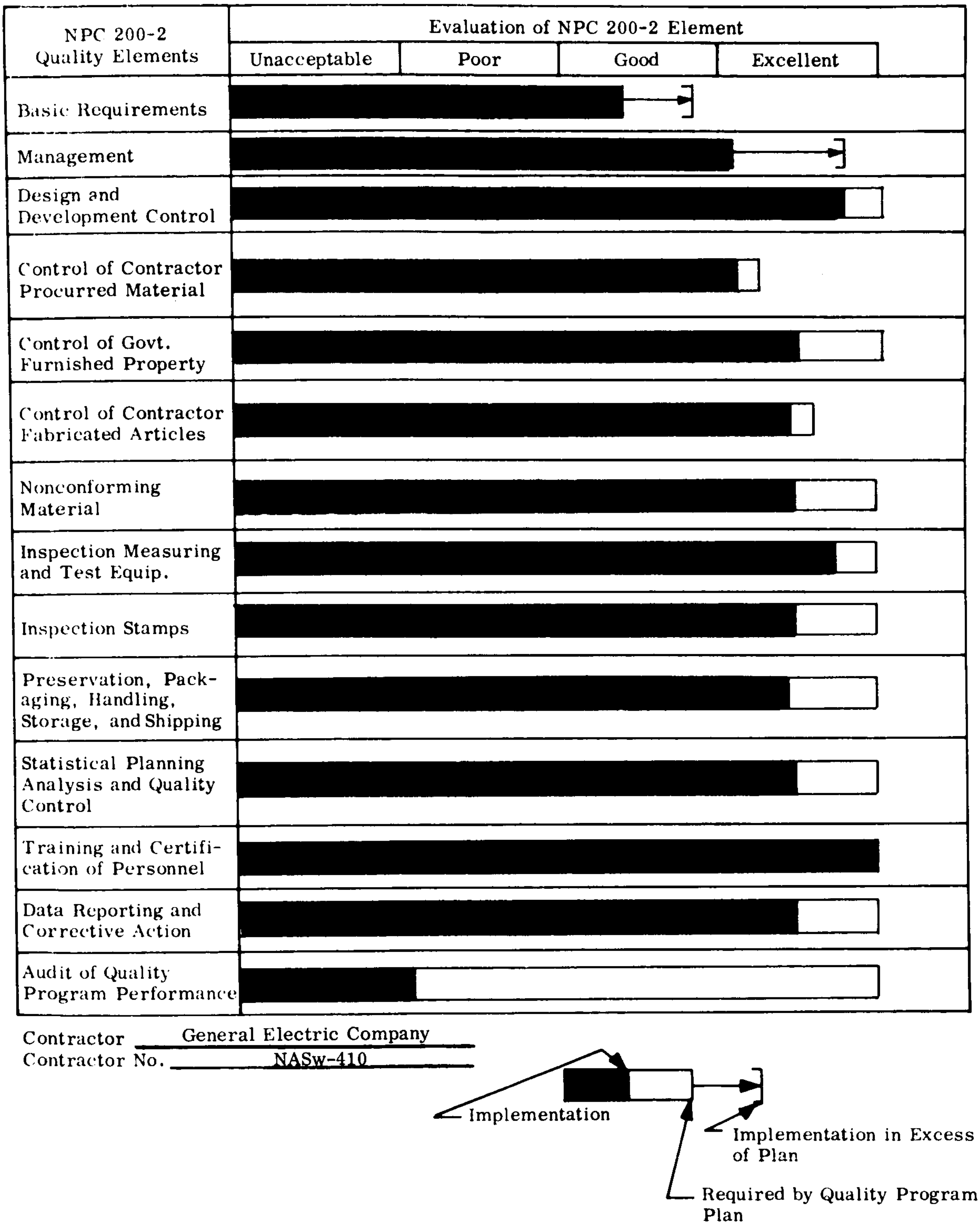


Figure 2-50. Saturn V ESE Quality Assurance Evaluation, Based on NPC 200-2

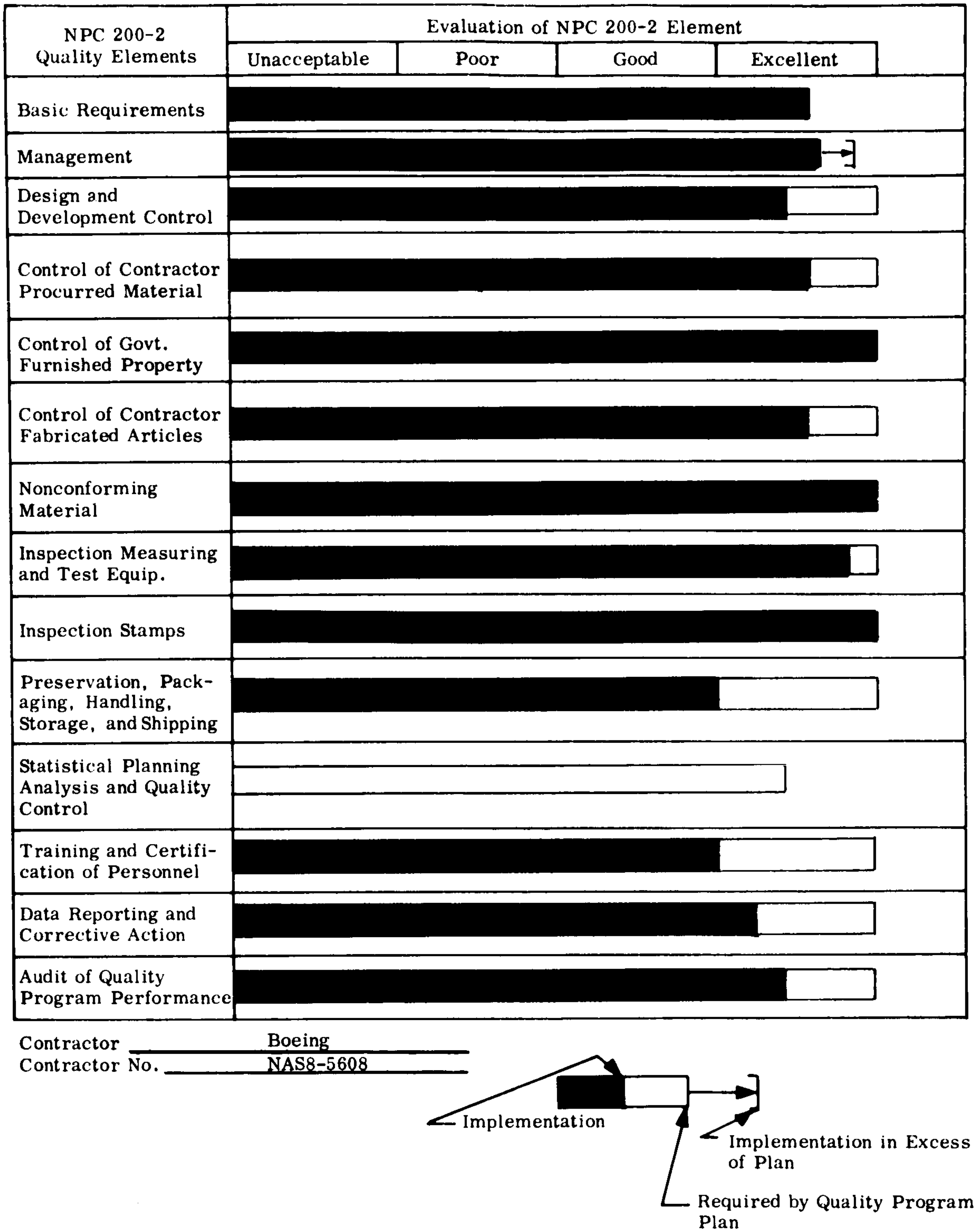


Figure 2-51. Saturn V GSE Quality Assurance Evaluation, Based on NPC 200-2

SECTION 3: APOLLO RELIABILITY AND QUALITY ASSURANCE PROGRAM MANAGEMENT

3.1 GENERAL

This section presents the status of reliability and quality activities necessary to develop the broad base required to manage the Apollo Reliability and Quality Assurance (R&QA) Program. The information included represents a summary of those functions and activities of the Apollo R&QA Office and MSF Centers to provide the cohesive force required to plan, implement, and control a meaningful and coordinated reliability and quality effort.

3.2 PROGRAM PLANNING

Status of program planning by R&QA Offices in the Apollo Program Office and at MSF Centers remains as previously reported with one exception. KSC had planned to prepare the initial revision to the KSC R&QA plan during this period. However, this revision has not been prepared, and no estimated revision date is available.

3.3 MSF CENTER STATUS REPORTING

3.3.1 MANNED SPACECRAFT CENTER

In addition to preparing a quarterly R&QA status report, ASPO has established formal monthly program reviews with major contractors. Quality reviews emphasize nonconformance and corrective action at MSC and at contractors. Reliability reviews generally report the eleven tasks contained in the MSC/ASPO Reliability Program Plan. Both contractor and NASA action items are established at the reviews. These reviews, in conjunction with quarterly reports, are utilized to maintain control over MSC contractors and to replace monthly contractor status reports. Apollo R&QA Office personnel are participating in these reviews to obtain management visibility.

In the latest MSC R&QA status report, two significant management problems were indicated:

a. Critical design and test documentation is frequently late and of poor quality when submitted to NASA/MSC for review and approval.
b. Because of a manpower shortage across the program, there has been very little attention given to the reliability and quality aspects of the GSE equipment, even that considered mission essential.

3.3.2 KENNEDY SPACE CENTER

The KSC R&QA Office has established requirements for the operating divisions to prepare reports for inclusion in KSC R&QA status reports. The initial KSC R&QA report was prepared in November and will be issued quarterly commencing with the January 1966 issue.

3.3.3 MARSHALL SPACE FLIGHT CENTER

The Saturn V Program Office is presently engaged in developing the initial Saturn V R&QA status report for issuance on 15 March 1966. In addition, MSFC plans to issue a Saturn V Monthly Quality Status Report beginning in January 1966.

3.4 MSF CENTER PROGRAM AUDITS

The Saturn IB and Saturn V Program Offices at MSFC are performing continuing reliability and quality audits of launch vehicle and GSE contractors. The audits measure implementation of NPC 250-1 and NPC 200-2 by MSFC contractors and evaluate compliance of contractors to requirements of the specifications.

A summary of major contractor audits conducted and scheduled by MSC is depicted by Figure 3-1. As a result of a meeting held with prime contractor personnel, there has been a slight improvement in the timeliness of corrective action by contractors relative to the problems uncovered by quality system audits. Timeliness of corrective action, however, continues to be a major problem area, and effort will be expended to resolve this situation. The MSC audit plan and schedule may be modified to permit early auditing of hardware programs experiencing unique or critical problems and to permit followup audits on programs in which prior audits have indicated action items of special significance.

Space System	1965				1966		
	S	O	N	D	J	F	M
Lunar Excursion Module (GAEC)	R▼			Q▼			
Guidance and Navigation (ACED)			Q▼				
Guidance and Navigation (MIT)							R▽Q
Command and Service Module (NAA)		Q▼	R▼				

Symbols:

▽ Scheduled Completion Date — R Reliability Audit

▼ Actual Completion Date — Q Quality Audit

Figure 3-1. Summary of MSF Center Reliability and Quality Audits of Prime Contractors

There are no schedules available from the operating divisions at KSC, but they are performing reliability and quality audits of facility and GSE contractors. During October, reliability audits were conducted on four contractors, and quality audits were conducted on 16 contractors.

3.5 TECHNICAL IMPLEMENTATION

Coordination of activities among NASA Apollo program reliability organizations is being accomplished to assure a successful R&QA program. This coordination effort is being applied in the following areas where integrated effort will serve to improve program reliability and provide maximum program benefit.

3.5.1 SYSTEMS NONPERFORMANCE ANALYSIS

As directed in the 20 August memorandum entitled, "Apollo-Saturn Failure Summaries and Trends," the Apollo R&QA Office has provided the Center coordination necessary to obtain failure information for the September and November presentations to the MSF program review meetings. Although the November meeting was cancelled, the presentation was prepared in order not to lose the continuity of the trend information.

The experience gained from previous presentations has provided the background for the improved requirements specified in a 28 September memo prepared by the Apollo R&QA Office and entitled, "Reliability Presentation to Management and Program Managers." Another memo aimed at further improving the quality of these presentations is currently being prepared to reflect the increased capability of the Centers to provide more specific information in relation to the 200- and 500-series hardware.

As a result of the first MSF program review, Apollo program management recognized the need for Apollo failure information terms, definitions and data classifications. Preparation of a program directive on failure reporting resulted. At the 3 November 1965 APO monthly meeting, the initial draft of this proposed directive was presented. Based upon comments received as a result of an APO Staff review, a directive draft was presented for the Program Director's signature on 15 December 1965. The requirement of failure information for the MSF program reviews and the AS-201 flight readiness review has focused the Centers' attention on the necessity for accurate and timely failure information.

3.5.2 SINGLE-POINT FAILURE ANALYSIS

Each MSF Center is intensifying efforts to identify and act upon single-point failures by implementing extensive failure mode and effects analyses as a basis for preparing criticality information. The Apollo Program Office is preparing a directive which formalizes previous instructions and establishes an operating procedure to assure a coordinated effort for reporting and controlling potential single-point failures. The directive will establish program policy, define single-point failures, and identify responsibilities and actions required by cognizant organizations. This formal procedure will assure that single-point failures are given adequate review with concurrence of action by established levels of authority and will define means for coordinating required action with other reviews such as critical design reviews and flight readiness reviews.

3.5.3 TRAINING

Management of training activities at the Centers has focused effort in the critical areas of new program development and implementation, as well as in determining the effectivity of existing programs. In this latter regard, surveys have been conducted of NASA personnel having graduated from Quality Surveyor Seminars to determine post-graduate utilization of knowledge gained at seminars. Results of these surveys have provided training management with realistic and factual requirements.

Under the direction of the Apollo R&QA Office, two new courses have been implemented in this period. These are the Reliability Engineering Seminar and the Electromagnetic Compatibility Awareness Seminar. The program of instruction for the Reliability Engineering Seminar was developed by the General Electric Company in conjunction with the ARINC Research Corporation. These seminars have been conducted at six NASA Center locations. The purpose of these seminars is to develop an understanding and appreciation for the value of the Apollo reliability program by managers, systems engineers, project engineers, and other NASA and contractor personnel not directly associated with the reliability program. Emphasis in this program has been directed toward the benefits of the "Reliability Disciplines" in relation to the probability of over-all mission success. During this quarter, 224 attendees have participated. Approximately 65 percent of the attendees have been NASA personnel with the remainder representing NASA contractor organizations.

The Apollo R&QA Office has also directed the development of a handbook on the principles and practices of electromagnetic compatibility. The purpose of this text is to provide reference source information for use in the presentation of seminars on Electromagnetic Compatibility Awareness. Upon completion of this text, an industry-wide workshop was held at Daytona Beach in November 1965. The purpose of the workshop was to enable 43 nationally recognized EMI/EMC experts to participate in review of the text material and lectures.

Lecture sessions for this workshop were prepared by General Electric Company in conjunction with NASA/MSFC, Jansky and Bailey Inc., and Interference Consultants, Inc. At the end of the workshop and following each lecture session, evaluation and critiques were conducted.

Current planning is to implement scheduled Electromagnetic Compatibility Awareness Seminars at all major NASA Centers, commencing in February 1966.

3.5.4 MOTIVATION

The Apollo R&QA Office has initiated the accumulation of information on the various Apollo contractor motivation programs. This information will be utilized to assist the MSF Centers and Apollo contractors in taking optimum advantage of motivation techniques to complement their reliability and quality assurance programs. Effort was also initiated to develop an Apollo motivation film. The Apollo R&QA Office is also coordinating this activity with other NASA offices.

3.5.5 PARTS AND MATERIALS PROGRAM

The MSFC Apollo Parts Information Center, APIC, has continued activities to meet the requirements of the Apollo R&QA Program Plan (NHB 5300.1).

To encourage information and data contribution, APIC has developed the "APIC Management Presentation" which is a twenty-five minute, narrated slide program.

This presentation, given to Apollo program management participants, explains APIC and its advantages to the potential APIC users. To date, presentations have been given to approximately 440 people representing twenty-eight functional NASA and contractor organizations at KSC, Michoud, MSFC, and MTO.

During this period, the APIC data base increased with both KSC and MSFC making contributions. However, of the approximately 25,000 parts in the data base, only 1500 include sufficient information and data for program dissemination. The ability of APIC to provide outputs in accordance with NHB 5300.1 is directly related to the maturity of the APIC data base. The Apollo R&QA Office will assist in developing this base by coordinating with MSF Centers that are responsible for contributing by means of the Apollo Parts and Materials Management Panel.

The MSC-ASPO parts and materials program has become more effective because the basic foundation has been established by previous accomplishments which support current efforts. During this period, a management panel meeting and technical working group meetings were held to review contractor performance and compliance with ASPO parts and materials requirements. Also discussed were critical problems and the recommended corrective actions. Resolution of some of these problems has already resulted. Data gathered at North American and at CSM subcontractors and suppliers was successfully cross-indexed, encoded, keypunched, converted to tape, and printed out with LEM and G&N data. The Apollo Spacecraft Parts List is now more than 90 percent complete.

KSC has initiated activities to generate a parts qualification list. In addition, the KSC unsatisfactory condition report and corrective action procedures are being revised to improve their effectivity.

Gemini spacecraft failures occurring on flight hardware subsystem components and parts at the McDonnell Aircraft Corporation, Gemini subcontractors and suppliers, and KSC are being analyzed on a monthly basis. Seven reviews of these analyses, entitled, "Gemini Spacecraft Malfunction Summary Review," have been distributed to appropriate Apollo Center and NASA, APO and Gemini management personnel. The most significant R&QA hardware problems have been in the areas of (1) pyrotechnics, (2) valves and regulators, and (3) switches, relays, and circuit breakers.

The monthly McDonnell "Project Gemini Spacecraft Equipment Malfunction Summary Report" for each Gemini spacecraft subsystem is now being incorporated into the MSFC APIC information system for the cross referencing of some 7500 Gemini spacecraft failures with similar Apollo spacecraft hardware failure information, part numbers and suppliers.

3.5.6 CREW RELIABILITY STUDIES

The third of a series of lunar landing flight simulations was completed on 24 September 1965. Results from the three missions indicate a high reliability in performance of flight control and switching tasks. A final report of the study is presently being prepared and will be available in early 1966.

In addition, the Air Force funded a study to determine amount of skill retention by crews after a period of time. Results of this study indicate a high level of skill retained after a time lapse of from 30 to 70 days.

3.5.7 RELIABILITY MANAGEMENT STUDY

Activity continued with a review of the recently initiated Apollo Directive System. Issued directives were reviewed to determine applicability and relationship of the directives to activities of the Apollo R&QA Office and to define action required. Of the directives, Apollo Program Directive No. 6, "Sequence and Flow of Hardware Development and Key Inspection, Review, and Certification Checkpoints," was found to be of primary interest. Figure 3-2 shows the percentage of Program Directive No. 6 elements presently being implemented by the Centers.

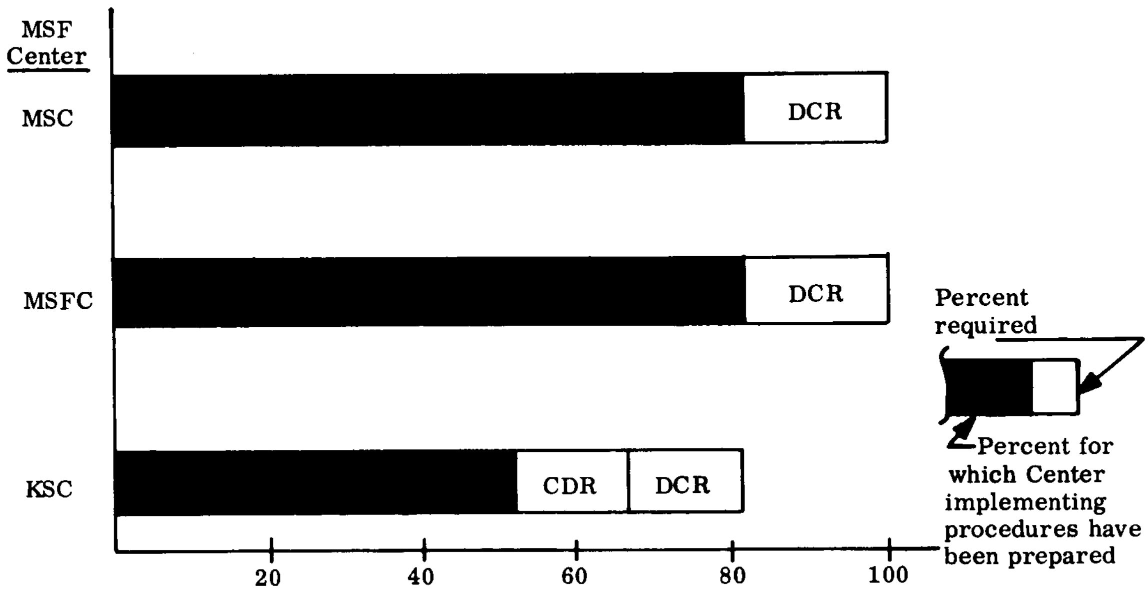


Figure 3-2. Percentage of Program Directive No. 6 Elements Required and Implemented

Program Directive No. 6 was issued too late in the program to require preparation of instructions for PDR's so this has been assumed to have been accomplished. Procedures which have not been issued to implement Program Directive No. 6 are:

- Design Certification Review - MSC, MSFC, and KSC
- Critical Design Review - KSC

Requirements for preparation of COFW procedures exist only at MSC and MSFC, as specified by Apollo Test Requirements (NPC 500-10).

The study resulted in preparation and publication of the "Reliability Program Flow Diagram" which correlates reliability activities with the basic program checkpoints. Reliability requirements were defined in accordance with program phases established by Apollo Program Directive No. 6 to furnish a firm basis for evaluation of stages, modules, and systems on an individual flight basis. Reliability activities were portrayed according to particular program phases during which they normally occur. Significant accomplishment or completion of an activity during any program phase results in verification during the program reviews to be conducted at each defined checkpoint.

3.5.8 APOLLO PROGRAM RELIABILITY AND QUALITY STANDARDS

As the program progresses and hardware is delivered, the need for new program standards is diminishing. A summary and description follows for reliability and quality standards and procedures in process.

3.5.8.1 Identification for Traceability Standard

This standard has been coordinated with the Centers and KR and is expected to be published in December 1965. The standard establishes the requirements for article identification on drawings, specifications, and technical documents by Centers and Apollo suppliers to facilitate failure analysis and corrective action and to provide complete article retrieval capability.

3.5.8.2 Quality Audit Handbook

The Quality Audit Handbook (NHB 5330.6) was prepared as a guide for Apollo program personnel in performing audits of specific quality activity areas of a contractor's quality program. It is based upon the requirements of NPC 200-2 and may also be used for performing audits of specifically indicated areas of a supplier's inspection system based on NPC 200-3. Nineteen quality activity areas are included. Each activity area is prepared in an outline format covering the requirements for that specific area in the three categories of procedures, performance, and records.

3.5.8.3 Apollo-Saturn Reliability and Quality Assurance Requirements for KSC Procurements

This document implements KSC policy for the inclusion of reliability and quality requirements in KSC procurements. It identifies requirements, and establishes procedures and organizational responsibilities for integrating R&QA requirements into applicable procurements and existing work orders.

3.5.8.4 Apollo Metrology Requirements Manual

This manual has been coordinated with the Centers and KR and has been approved for publication as NHB 5300.2. It is scheduled to be published in January 1966. The manual establishes specific requirements and associated criteria for a coordinated metrology system for developing and controlling calibration practices for standards and measuring equipment used in the development, manufacture, inspection, and test of hardware for the Apollo mission.

3.5.8.5 FMECA Standard

A coordination draft of the FMECA standard, which includes many new inputs obtained from a wide and extensive critique of earlier drafts, was completed by the Apollo R&QA Office. It will provide a common procedure for conducting failure mode, effects, and criticality analyses of hardware end items.

3.5.8.6 Apollo Contamination Control Handbook

A review of the general technology of contamination control as it relates to and affects Apollo R&QA efforts has been undertaken. As a result, the Apollo contamination control handbook has been prepared and is currently being reviewed prior to coordination with the Centers. This handbook was prepared to bring the known information and techniques into a single source for easy reference and use and to provide the criteria for developing, implementing, and maintaining an effective contamination control effort. Coordination with KR is planned for possible NASA-wide use.

3.5.8.7 Equipment Logs and Apollo Parts Program

Coordination drafts of standards on equipment logs and Apollo parts programs which were previously completed are being made available to the MSF Centers so that their usefulness as working documents can be evaluated.

3.5.9 APOLLO CONTROL CENTER

Development and preparation of a series of reliability and quality assurance information charts for inclusion in the Apollo Control Center has been initiated. Displays have been prepared to portray current significant information of the Saturn IB, Saturn V, and spacecraft programs. Both over-all program and specific flight vehicle and GSE data have been considered for inclusion on the displays. Some of such data are mentioned below:

a. An illustration of reliability and quality assurance requirements placed upon stage, module, and GSE contractors and current compliance and performance to requirements.
b. A display of mission success and crew safety reliability degradation for each mission phase. Predictions and assessments, where available, will be plotted.
c. A display portraying attained reliability versus goal for each flight mission.
d. An illustration of the relative contribution of unreliability of each stage and module for the over-all mission.
e. Identification of the five most critical elements for stages, modules, and GSE for specific flight missions.

3.5.10 KSC ACCEPTANCE AND BUY-OFF PROCEDURES

The Apollo R&QA Office has initiated a review to identify and assess the plans, procedures, and actions associated with Government Quality Assurance acceptance of LC-37B facilities and ground support equipment at KSC. The S-IVB Auxiliary Propulsion System (APS) was selected as a representative GSE system for APO review.

Preliminary conclusions based upon a five-week review of the APS system at KSC are as follows:

a. Checkout and buy-off procedures for the major components of the APS systems are written and in use for the installation of this system on LC-34. Similar equipment will be delivered and installed on LC-37B. The procedure in use on LC-34 can, with minor modifications, be used for LC-37B.

b. Leak and functional test procedures have been written to check the entire APS system prior to the buy-off of the APS system as a functional part of the launch complex.

c. While the design documentation (and associated test procedures) is well defined for the major components of the APS system, no documentation that defines the APS system as a whole has been located. The over-all APS leak and functional test procedures are designed to test the system as a whole and appear to accomplish this purpose. However, lack of an over-all systems documentation tree (as defined in MIL-D-70327 and NPC 500-1) presents the danger of overlooking important details that are not specifically a part of any one of the APS components.

3.5.11 QUANTITATIVE RELIABILITY ANALYSIS

The development of a compatible family of reliability models is progressing. The Apollo R&QA Office conducted a review of MSC reliability analyses of the Apollo spacecraft on 30 November through 2 December. The topics discussed at the review were system logic diagrams for the AS-204 mission, and the LEM system logic diagrams, and failure rate data for the AS-504 mission. LEM analyses and models prepared by Grumman are generally acceptable for inclusion in the spacecraft model, but additional emphasis is required for completion of a validated command service module model. Spacecraft analysis for the AS-201, AS-202, and AS-203 missions will be accomplished by extrapolating data from the AS-204 mission analysis and will be prepared by the Apollo R&QA Office.

The following work schedule recommendations resulted from the review meeting:

a. MSC will furnish an official documentation schedule and determine how MSC/Apollo R&QA Office schedules can best be synchronized to provide maximum lead time for level I mission reliability analyses.

b. Representatives of MSC and the Apollo R&QA Office will meet to coordinate profile work schedules on specific missions and define a plan of action to assure profile compatibility at levels I, II and III.

A presentation of the reliability mission profile based on the design reference mission was given to MSFC by the Apollo R&QA Office on 15 November 1965. On 10 December 1965, an internal management review was held at MSFC with Apollo R&QA Office personnel participating to review an updated model for the AS-501 launch vehicle. Since MSFC intends to use the reliability profile in future modeling activities, a thorough review of the profile activity to date was conducted at MSFC on 17 December 1965.

During this report period, personnel from MSFC, Michoud, Boeing Co., Chrysler Corp, and ARINC Corp reviewed failure rate data from the mission model at Daytona Beach for periods of two days. During these visits, failure rate data was obtained by these personnel for use in their modeling activity.

Analyses of the prelaunch period from T -50 hours to liftoff, for the AS-504 mission were initiated by the Apollo R&QA Office. The analyses will include data pertaining to the spacecraft, launch vehicle, launch complex, and associated GSE.

Definition of countdown, hold, and recycle capability and the probabilities of success will depend upon the development of the Apollo R&QA Office analysis and its application of available information from program sources.

3.5.12 IMPLEMENTATION OF RELIABILITY AND QUALITY ASSURANCE REQUIREMENTS

The Unified "S" Band (USB) Transponder, manufactured by Motorola Co., is used in the Apollo CSM, LEM, and IU. The procuring Apollo contractors and MSF Centers have imposed reliability and quality requirements upon Motorola that vary in some areas. Representatives from Apollo contractors, MSF Centers, and APO met with Motorola in September 1965, to review the difference in requirements and to establish a program for resolution. The following items were discussed.

a. Specific problems in implementing and interpreting soldering specifications: NPC 200-4, MSFC-Proc-Std-158B and MSC-ASPO-S-5B.
b. One hundred percent inspection requirements of critical parameters both at source inspection and incoming inspection.
c. Multiple inspections requirements of in-process workmanship resulting in 300 to 400 percent inspection.
d. Desirability of resident NASA representative for a common interpretation of the varied specifications and requirements.
e. Common procedures for material review board.
f. Common parts usage.
g. Common quality assurance program plan.

During the meeting a detailed program was planned, and schedules were established to resolve the differences in requirements.

As a result of this meeting, Collins Radio Corporation has drafted recommended amendments to NPC 200-4 and has proposed to the other participating Apollo contractors that NPC 200-4 with the recommended amendments be accepted as the soldering requirements specification.

Once agreement among the Apollo contractors is achieved, the recommended amendments will be submitted to NASA for acceptance. Formal submittal to NASA should be accomplished by 31 December 1965, and final resolution of the soldering specification problem at Motorola is expected by the end of January 1966.

APPENDIX A

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APPENDIX B

LIST OF ABBREVIATIONS AND CODES

ACE - Acceptance Checkout Equipment
ACED - AC Electronics Division
AEDC - Arnold Engineering Development Center
AMPTF - Apollo Mission Planning Task Force
APIC - Apollo Parts Information Center
APO - Apollo Program Office
APS - Auxiliary Propulsion System
ASPO - Apollo Spacecraft Program Office
ATR - Apollo Test Requirements

BP - Boiler Plate Spacecraft

CARR - Customer Acceptance Readiness Review
CCSD - Chrysler Corporation Space Division
CDR - Critical Design Review
CM - Command Module
C/O - Checkout
COFW - Certification of Flight Worthiness
CSM - Command/Service Module
CTN - Certification Flight Network

DAC - Douglas Aircraft Company
DCR - Design Certification Review
DDAS - Digital Data Acquisition System
DEI - Design Engineering Inspection
DPS - Descent Propulsion Subsystem
DRM - Design Reference Mission
DTCS - Digital Test Command System
DTMS - Digital Test Monitoring System

EBW - Exploding Bridge Wire
ECP - Engineering Change Proposal
ECS - Environmental Control Subsystem
EDS - Emergency Detection System
ELS - Earth Landing Subsystem
EPS - Electrical Power Subsystem
EMC - Electromagnetic Compatibility
EMI - Electromagnetic Interference
ESE - Electrical Support Equipment
ESI - Electronic System Integration
ETR - Eastern Test Range

FACI - First Article Configuration Inspection
FCI - Flight Critical Items
FEA - Failure Effects Analysis
FEAT - Final Engineering Acceptance Test
FMEA - Failure Mode Effects Analysis
FMECA - Failure Mode Effects and Criticality Analysis
FRR - Flight Readiness Review
FRT - Flight Readiness Test
FTA - Flight Test Article

GA - Government Agency
GAEC - Grumman Aircraft Engineering Corporation
GE/ASD - General Electric Company/Apollo Support Department
GETS - Ground Equipment Test Set
GFE - Government Furnished Equipment
G&N - Guidance and Navigation
GOSS - Ground Operational Support System

GSE - Ground Support Equipment
GSFC - Goddard Space Flight Center

IBM - International Business Machines Corporation
IMU - Inertial Measurement Unit
IU - Instrument Unit

KSC - Kennedy Space Center

LC - Launch Complex
LCC - Launch Control Center
LEM - Lunar Excursion Module
LES - Launch Escape Subsystem
LH_2 - Liquid Hydrogen
LJ - Little Joe Launch Vehicle
LOR - Lunar Orbital Rendezvous
LOX - Liquid Oxygen
LTA - LEM Test Article
LUT - Launcher - Umbilical Tower
LV - Launch Vehicle
LVDA - Launch Vehicle Data Adapter
LVDC - Launch Vehicle Digital Computer
LVPFR - Launch Vehicle Preliminary Flight Readiness

MCC - Mission Control Center
MDS - Malfunction Detection System
MILA - Merritt Island Launch Area
MIT - Massachusetts Institute of Technology
MLL - Manned Lunar Landing
MRB - Material Review Board
MSC - Manned Spacecraft Center
MSF - Manned Space Flight
MSFC - Marshall Space Flight Center
MSFN - Manned Space Flight Network
MSS - Mobile Service Structure
MTBF - Mean Time Between Failure
MTO - Mississippi Test Operation

NAA - North American Aviation, Inc.
NASA - National Aeronautics and Space Administration
NMI - NASA Management Instruction
NPC - NASA Publication Control (number)

ODOP - Offset Doppler Electronic Tracking System
OMSF - Office of Manned Space Flight

PCM - Pulse Code Modulation
PDP - Program/Project Development Plan
PDR - Preliminary Design Review
PERT - Program Evaluation Review Technique
P/N - Part Number

QPR - Quarterly Project Review

RCA - Radio Corporation of America
RCS - Reaction Control Subsystem
R&D - Research and Development
RFI - Radio Frequency Interference
RFP - Request for Proposal
R&QA - Reliability and Quality Assurance

SACTO - Sacramento Test Operation
S/C - Spacecraft
SCS - Stabilization and Control Subsystem
SDBF - Systems Development Breadboard Facility
S&ID - Space and Information Systems Division of NAA
SLA - Spacecraft - LEM Adapter
SM - Service Module
SPFS - Single Point Failure Summary
SPS - Service Propulsion Subsystem
STL - Space Technology Laboratory
SWIP - Super Weight Improvement Program

TM - Test Module
TRW - Thompson Ramo Woolridge

UHF - Ultra High Frequency
ULD - Unit Logic Device

VAB - Vehicle Assembly Building
VHF - Very High Frequency

WSMR - White Sands Missile Range